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Natural Radioactivity Contamination Problems

Conference of Radiation Control Program
Directors, Inc.

Prepared for

Office of Radiation Programs
Washington, DC

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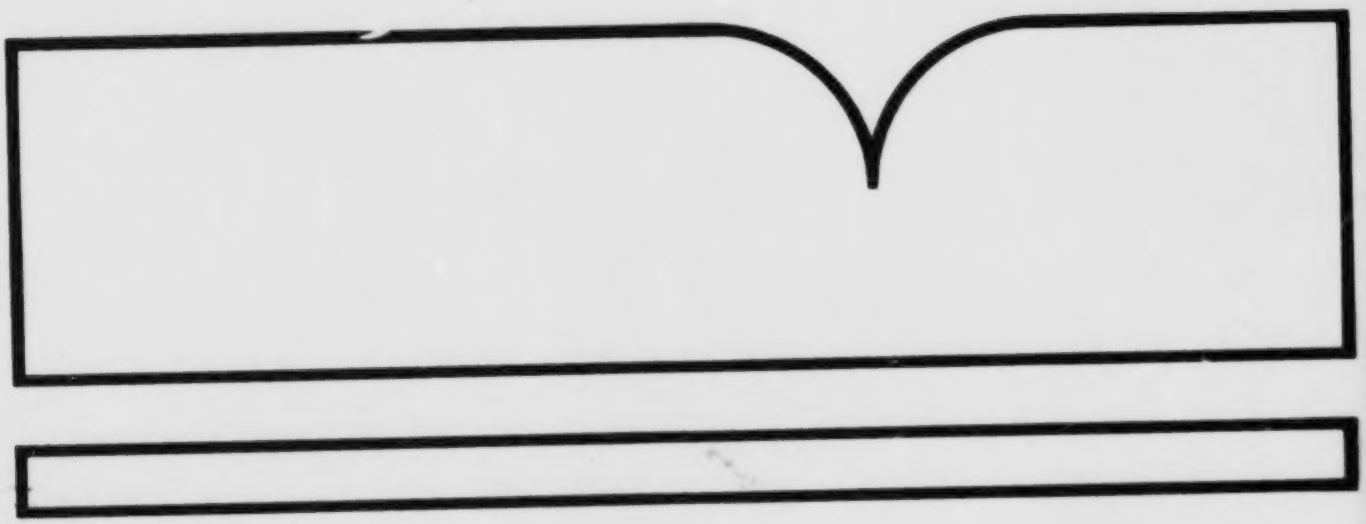

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16. ABSTRACT

Levels of naturally occurring radionuclides associated with the bauxite, columbium-tantalum, phosphate, tin, pumice, and titanium mineral extraction industries are reported. Data is also presented on radioactivity measurements in ground water, in selected geothermal waters, and in oil production brines. Radiation protection guidance is provided for uranium recovery from wet-process phosphate plants, for soil contamination limits, and for radiological exposure in natural caves. Dose pathways from incidental uses of naturally occurring radioactive materials are presented. Model state regulations for protecting public health and safety from use and disposal of naturally occurring radioactive material are outlined.

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Bauxite	Ground Water	Radiation Surveys	0807
Niobium	Geothermal	Uranium Mining & Milling	0702
Tantalum	Uranium Ore	Mineral Extraction Indus.	0809
Phosphate	Regulations	Technologically Enhanced Radioactivity	1108 0808
Zircon	Titanium	Radiation Protection Guidance	0806
Tin	Caves		
Pumice			

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Conference of Radiation Control Program Directors, Inc.

NATURAL RADIOACTIVITY CONTAMINATION PROBLEMS

REPORT NO. 2

Published by
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Program Directors, Inc.

NATURAL RADIOACTIVITY CONTAMINATION PROBLEMS

REPORT NO. 2

A REPORT OF THE COMMITTEE

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CONFERENCE OF RADIATION CONTROL PROGRAM DIRECTORS, INC.

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FOREWORD

The Conference of Radiation Control Program Directors is an organization whose membership is comprised of all directors of radiation control programs in the 50 States, the Territories, and some large municipal agencies. The Conference was formed to serve as a mechanism for providing a more functional means of exchanging information between State and Federal agencies as well as between States themselves in areas of mutual concern or interest. Additional objectives and purposes of this Conference are to:

(1) Promote radiological health in all aspects and phases.

(2) Encourage and promote cooperative enforcement programs with Federal agencies and between related enforcement agencies within each State.

(3) Collect and make accessible to all radiation control program directors such information and data as might be of assistance to them in the proper fulfillment of their duties.

(4) Foster uniformity of radiation control laws and regulations.

(5) Support programs which will contribute to radiation control.

(6) Assist members in their technical work and development.

(7) Exercise leadership with radiation control professionals and consumers in radiation control development and action.

The Office of Radiation Programs of the Environmental Protection Agency carries out a national program designed to evaluate public health impact from ionizing and nonionizing radiation, and to promote development of control necessary to protect the public health and ensure environmental quality. In this regard, the Environmental Protection Agency (1) develops radiation protection standards, criteria, and guidance,

(2) conducts special environmental studies, (3) evaluates radiation exposure trends, (4) assesses radiation control technology, and (5) provides technical assistance to State and local agencies responsible for radiation control.

The Office of Radiation Programs, through funding and direct technical assistance, supports the Conference of Radiation Control Program Directors, Inc., in its objectives and activities to assure an effective Federal/State partnership in limiting unnecessary environmental and public radiation exposure. Selected Conference reports are published by the Environmental Protection Agency and are distributed to Federal, State and local radiation protection personnel, industry, libraries, laboratories, and other concerned groups and individuals. These publications are available from the Louisiana Nuclear Energy Division and/or the National Technical Information Service.

Readers are encouraged to report errors or omissions to the Conference.

John R. Stanton

John R. Stanton
Chairman
Conference of Radiation Control
Program Directors, Inc.

PREFACE

Naturally-occurring radionuclides are ubiquitous in the environment. Under various circumstances, these radionuclides, primarily from the uranium and thorium decay series, can contaminate the environment to the extent that they pose real or potential public health risks. The investigation and regulatory control of the impacts of most of these sources have been greatly overlooked by Federal and State agencies in the past. In order to initiate effective control measures in this radiation protection problem area, the Conference of Radiation Control Program Directors, Inc., established a Task Force to assess contamination by naturally-occurring radionuclides and assist the States and Federal agencies in developing appropriate radiation protection guidance and criteria. The Task Force consisted of representatives from several State radiation control programs with resource persons from the Environmental Protection Agency. By action of the Conference Executive Committee, the Task Force became a Standing Committee in May, 1980.

The initial Report provided an assessment of the scope of the contamination problems, the priorities for radiation control efforts, and the Task Force's recommendations for problem resolution and implementation of effective control measures. The Report was intended to assist those persons or agencies interested in the protection of public health from naturally-occurring radionuclide contamination. This Report No. 2 is intended to provide an update and summary of the previous Report in addition to several new topics which the Task Force felt would be of general interest.

This document should be of special interest to State, local, and Federal radiation protection personnel in the United States and other countries.

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HISTORY AND PURPOSE OF THE COMMITTEE

Task Force No. 7 on Natural Radioactivity Contamination Problems was established by the Executive Committee of the National Conference of Radiation Control Program Directors in 1975 as an extension of Workshop No. 5 of the 1974 Annual Meeting of the Conference.

The charge to this Task Force is to:

(1) Provide assistance to the Conference, individual States, and Federal agencies in scoping the problem of contamination by natural radioactivity;

(2) Assist in developing appropriate radiation protection guidance and criteria;

(3) Assess the impact of naturally-occurring radioactivity contamination in the general environment and the Conference member States; and

(4) Serve as a focal point for State input to the programs of Federal agencies.

The charge given necessarily implies certain responsibilities in which the Task Force must assist the appropriate State and Federal agencies. These include the following:

(1) Defining the radiation level or concentration or stage of processing in which naturally-occurring radioactive material (NORM) becomes a contamination to the environment.

(2) Identifying who has authority to develop and implement guidelines and criteria for enforcement action;

(3) Identifying the impact that naturally-occurring radioactive contamination has on the general population;

(4) Examining the need for control on the use of products and byproducts containing NORM and the associated economic impact of such control;

(5) Defining the sources currently known or suspected to contain possibly hazardous amounts of NORM and describing other potential problem areas; and

(6) Recommending priorities for control programs to address NORM problems.

In addition the membership and charge of the Conference Task Force No. 9 on Establishment of Soil Contamination Limits was transferred to the Committee in 1979. This charge was as follows:

> Serve as an expert group representing State radiation control program expertise and viewpoints regarding all matters pertaining to the establishment of soil contamination limits for long half-life radioactive materials (excluding mining and milling operations), with particular emphasis on the following:
>
> > Provide assistance to the Federal Agencies in scoping the problems of soil contamination and identifying the need for contamination limits. Assist, upon request, in developing appropriate guidance and criteria.
>
> Review proposed guidance and criteria for its effectiveness in addressing the specific problems, practical feasibility, and impact on State radiation control programs.
>
> Serve as the focal point for input of Conference member-states to the programs of the Federal agencies.

In October of 1979, during the initial meeting of the combined Task Forces, it was felt that the reference excluding mining and milling operations should be removed from the reconstituted responsibilities, as it was now within the purview of this group.

In May 1980, the Task Force on National Radioactivity Contamination Problems, by action of the Conference Executive Committee, officially became the Committee on Natural Radioactivity Contamination Problems.

INTRODUCTION

Natural radioactivity and its associated radiological impacts have generally been overlooked in the past. Although there have been strict controls on other sources of radiation such as by-product material, X-ray machines, special nuclear material, etc., natural radioactivity control has been minimal, perhaps since it is "natural" rather than "man-made" radioactivity. This lack of strict controls has been due in part to the fact that the Federal government has limited jurisdiction over naturally-occurring radioactive materials. Control was left previously up the States, who often times did not have adequate programs to deal with radiation. While there are over 100 naturally-occurring radionuclides (see Attachment D), those related to public health problems are usually limited to the 30 or more radionuclides in the uranium and thorium decay series because of their relative abundance and toxicity.

The majority of the work of this Committee does not deal with what is usually referred to as truly natural radiation, but more appropriately is concerned with exposure to radiation occurring as a result of alteration of the natural sources by technology. It is the objective of this Committee to collect and study available information and data on NORM in the environment and to make recommendations to the Conference regarding the need for evaluating, monitoring, and controlling natural radioactivity.

In Report I, the Task Force developed a series of recommendations based on findings and conclusion of data. Model State regulations were developed for potential incorporation into the Suggested State Regulations for Radiation Control and adoption by those States where such action may be warranted. The problem areas listed by the Task Force in Report I were re-examined, updated and expanded where additional data had become available. In Report II, a NORM Inventory and Radiation Pathways Table

was prepared in part from State input requested by the Committee. Finally the Report provides Soil Contamination Limit Guidance, Suggested State Regulations for Control of NORM, and a series of recommendations.

INITIAL TASK FORCE REPORT - SUMMARY AND UPDATE

In its first report, (Natural Radioactivity Contamination Problems, EPA-220/4-77-015), the Task Force examined problems relating to naturally occurring radioactive materials (NORM). The following is a summary of this first report. References and much greater detail on the summarized sections can be found in the first report. More recent data will be found in subsequent sections of this second report.

A. The Phosphate Industry

Phosphate rock contains uranium and its daughter products, in concentrations far exceeding the average abundance in the earth's crust, and also concentrations of thorium and thorium's daughter products. The health significance of the uranium series is of more importance.

Two methods are used to process phosphate rock. The first involves wet-processing with sulphuric acid to produce phosphoric acid or phosphate fertilizers. The byproduct of this process is phospho-gypsum, which usually contains concentrations of radium-226 of 20 to 60 picocuries/gram (pCi/g). The second process produces elemental phosphorous by electric furnace reduction with silicon and coke. The waste product, slag, from the elemental phosphorous furnaces contains radium concentrations similar to those found in the phospho-gypsum. Land reclaimed from phosphate mining also contains radium-226 in concentrations generally between 10 and 30 pCi/g. Normally, soil contains between 0.1 and 3 pCi/g.

Exposure to the public occurs from direct exposure to gamma radiation from phospho-gypsum, mined land, slag, the phosphate fertilizer products; from ingestion of water contaminated with radium-226 (either naturally or as a result of mining or

processing); but most significantly, from inhalation of radon-222 and daughters which originate from the land and gypsum. Restrictions should be considered relative to construction over contaminated land.

Other exposure pathways exist, such as transfer of radium in phosphate livestock feed supplements to milk, and uptake of radium in food crops from fertilizers. These are believed to be of lesser importance. Also uranium is being recovered from phosphoric acid. It is presently estimated that 90% of the uranium in phosphoric acid can be recovered for less than $20 per pound. Several plants are currently utilizing a uranium recovery process. It is estimated that if all available uranium were being recovered, an additional 10 million pounds could be added to the domestic annual production.

B. Thorium and Daughter Products

Thorium constitutes 10 - 20 parts per million of the earth's crust. It exists in a relatively few insoluble minerals, and higher concentrations of it usually occur in placer deposits of monazite in stream and beach sands. Thorium is extracted from monazite using hot, concentrated solutions of sulphuric acid or sodium hydroxide. After further processing, the oxide is formed, which is reduced with calcium to give the purified metal.

Thorium-228, the third daughter of thorium-232, is carried over in processing from the ore to the finished thorium product. It is the parent of thoron. Consequently, handlers of thorium products face hazards of inhalation of thoron and daughters.

Thoron (radon-220) emanates from the mineral and ventilation is required to reduce the hazard from this radioactive gas.

Due to its short half life, thoron does not exist for a long enough time to diffuse far through the ground. Accordingly, the concentrations of thoron in air are less than

for radon-222, even though due to the abundance of thorium, the amount of thoron exceeds the amount of radon in the earth. On the other hand, the lung dose from exposure to one picocurie of thoron and daughters per liter of air is about 5.8 times the exposure to the same concentration of radon and daughters.

Taken collectively, the net result is that thoron presents a problem similar to radon, but of a slightly lesser magnitude.

Uses of thorium include:

Gas lamp mantles

Coating transfer wire for filaments in incandescent lamps and vacuum tubes

Heliarc welding with tungsten electrodes

Alloys of magnesium

Thorium oxide catalysts

Optical glass for lenses

Crucible construction for special melting operations and other ceramics

C. Radioactivity in Fossil Fuels

Fossil fuels contain trace quantities of naturally occurring radioactive materials in the uranium and thorium decay series.

Natural gas contains radon which emanates from geologic strata. The total annual dose committment of 2.7×10^6 man-rem appears insignificant compared to background radiation. There could be, however, a localized problem if radon concentrations exceed 350 pCi/l (STP) in natural gas. No recommendations have been made except that evaluation of uses close to the gas fields may be needed.

Oil contains trace quantities of uranium, thorium, and their daughters; however, the radiological impact of oil-fired power plants is insignificant when compared to coal-fired plants.

Brines associated with oil field production may contain radium-226 concentrations of several hundred picocuries per liter. Radon and daughters are also present and can form radioactive deposits of sludge which can precipitate in process equipment. A potential exists for contamination of workers involved with this equipment, as well as contamination of surface and ground water.

Uranium-bearing coal and lignite are found in the Western United States. The content of uranium averages about 0.008 percent and ranges from 0.001 to 10 percent in lignite from the region. By comparison, Wyoming coal averages about 0.003 percent and coal from Idaho, around 0.05 percent.

While there has been little radiological surveillance conducted around fossil fuel power plants, calculations done for a proposed two unit 500 megawatt electrical plant in Idaho indicate releases of airborne polonium-210 will exceed permissible standards applied to the nuclear industry. Closer studies of these plants are encouraged.

D. Radium and Radon in Ground Water

The concentration of radium and radon in ground water varies widely throughout the United States. Radium-226, while usually well below the EPA drinking water standard of 5 pCi/l, occasionally is found in excess of 50 pCi/l. Radon, an inert gas, can exceed 50,000 pCi/l. Radon is easily released from water with mild aeration. Subsequent inhalation of radon daughters from this radon may cause significant health effects.

Previous researchers have estimated 20 annual health effects (predominantly lung cancers) per million people using a water supply containing 500 pCi/l of radon. Due to the nature of this exposure, (daily, continuous, and of many years' duration) cumulative exposures can be high.

Further study, both in the laboratory and of epidemiologic data, are needed.

E. Mineral Extraction and Processing

The ores of many minerals often contain higher than average concentrations of uranium, thorium and daughter products. Exposure to airborne thoron or radon and daughters could occur when high concentrations of thorium or uranium exist in the ore mined from underground mines; however, little data exists except for the uranium industry. Other mineral ores which contain elevated levels of naturally occurring radioactivity include aluminum (bauxite), copper, fluorospar, phosphorous, titanium, vanadium, zirconium, and rare earths. Additional data on some of these industries is given elsewhere in this Report.

The occurrence of uranium with copper has been studied to a small extent. It has been found to be associated with certain specific geological conditions. Thus, it is a site specific phenomenon.

There are three regions in the United States where copper deposits are found: the Appalachian province, the Keweenaw Penisula in Michigan and the Cordilleran provide in the Southwest. Most copper is mined using the open pit method. Because the uranium content of copper ores ranges from less than 1 ppm to over 100 ppm, the existence of a hazard from use of copper wastes will depend upon the uranium content of the ore. Uranium is now being recovered at mines and copper extraction mills.

The mechanisms of exposure to radiation from the wastes from the copper industry are similar to the phosphate and uranium industry and include the following:

1. use of mill tailings in construction and agriculture
2. construction on reclaimed land
3. tailings pond seepage and mine water pumping
4. radon gas emanation
5. dust from waste piles

Copper mill tailings are rarely used in construction, except for roads near the mines. This was due in the past to a lack of population growth in the areas of mills and the characteristics of the tailings. Some commercial uses of the tailings have been demonstrated, but none are known to be in use.

Zirconium ores are ground and mixed with coke and chlorine, then heated. Hafnium is then extracted using solvent extraction methods, and further chemical processing occurs prior to reduction of zirconium chloride with magnesium to form the pure metal. Wastes from the process include insoluble radium in sludge and soluble radium salts in residues. The potential exists for contamination of ground water from seepage of water containing thousands of picocuries of radium-226 per liter.

The extent to which radioactivity is associated with other minerals is not known. A radiation survey of a small mineral display in Oregon (Attachment A) indicates that there is a need to perform sensitive radionuclide analysis on common minerals.

F. Radon in Caves

Potential radiation hazards from radon and daughters may exist in caves and in buildings air conditioned with cave air.

In most caves the concentration of radon is highest in the summer when air exchange is least and visitor occupancy greatest. Exposures to occasional visitors are not significant but may be high for workers in the caves. The EPA has recommended an annual limit of 4 WLM* for workers.

All caves should be surveyed, and control measures when instituted, should be done carefully so as to protect the cave formations and ecology. See Attachment B for additional information and guidelines.

*WLM is working level months

G. Radioactivity in Construction Materials

Since the average person spends most of his time indoors, exposures to radiation may occur from natural radioactivity in construction materials. Most of the work in this area has been done by the European scientific community. The highest concentrations of activity have been found in granite, pumice, clay brick, and other masonry, such as concrete made from fly ash and industrial slag.

Exposures to radon-222 and daughters can be significant in buildings constructed of these materials, especially where ventilation is poor.

Phosphate slag is used in Idaho and elsewhere as a paving material. Exposure rates on roads range from 15 to 40 μR/hr due to radium-226 and daughters in the slag.

H. Standards, Regulations and Recommendations

The Task Force, in its first report, discussed the regulations and standards in effect as they apply to use of naturally occuring radioactive material (NORM), and identified problem areas where criteria are needed to protect the public health. A recommendation was made that the states adopt uniform regulations for NORM. It was suggested that specific licenses be issued, and sample NORM licenses were included as an attachment.

The Task Force made nineteen recommendations concerning use of NORM including discouraging some uses of materials, outlining studies and monitoring needed, and encouraging development of criteria and guidelines.

The Report also included, as attachments, Idaho's proposed regulations for slag and tailings, sample regulations from other states, and a proposal for evaluating radioactivity in oil field brines.

BAUXITE PROCESSING

While aluminum is the most abundant element found in the earth's crust, bauxite is the only material which qualifies commercially as a source of alumina under present economical and technical conditions. Bauxite is an ore containing hydrated aluminum oxide minerals, such as gibbsite ($Al_2O_3 \cdot 3H_2O$), boehmite ($Al_2O_3 \cdot H_2O$), or diaspore ($Al_2O_3 \cdot H_2O$), and is formed by weathering processes acting on alumina-bearing rocks. Major impurities in the bauxite ores are iron oxides, aluminum silicates, and titanium oxides. A typical bauxite analysis appears in Table 1. The North American aluminum industry depends chiefly on deposits in Dutch Guiana, British Guiana, Jamaica, and the State of Arkansas. The latest figures from the Bureau of Mines Minerals Yearbook show the total amount of bauxite consumed in the United States to be nearly 14 million tons annually. Approximately 4 pounds of bauxite is required to produce 2 pounds of alumina which in turn, make 1 pound of aluminum.

The first step in alumina refining involves passing the raw bauxite through a "breaker" building where large lumps of bauxite are broken up and larger impurities such as limestone chunks are removed. In the U.S., aluminum refining plants utilize the Bayer or a modified Bayer process which begins with dried bauxite being mixed with caustic liquor in slurry tanks and pumped out of slurry to highly heated digesters. Additional caustic then dissolves alumina from the bauxite. The liquor is then pumped through settling tanks to remove spent bauxite residue. This "red mud" is heavier than the liquor and is drawn from the tank bottom out of the settlings. This residue contains uranium series radionuclides which have been concentrated from the original bauxite ore. Specific radionuclide data on several process samples appear in Table 2 and Table 3.

The separated liquor overflows the settling tanks. The liquor is then cooled and seeded with a fine alumina hydrate in large air-agitated tanks to precipitate crystals of hydrated aluminum oxide. Finally, the crystals are washed and heated in rotary kilns to drive off all water from the pure aluminum oxide. A flow diagram is shown in Figure 1. The resulting white powder is cooled and stored for shipment to aluminum reduction plants, industrial chemical processors and other users.[1]

In Louisiana, the red mud slurry, which was once discharged into the Mississippi River, is now being impounded at the rate of 7,000 tons per day on large acreage sites, and dried through evaporation. Ultimate disposition of the dried residue is unknown at this time as is the future land use associated with the impoundment area. The industries and others are actively seeking methods for converting red mud from a waste material to a useful product. Some possible areas of utilization are land reclamation, construction materials, or as a feed material for other processes utilizing the iron content. Any such use of red mud must be carefully evaluated from a radiological standpoint, particularly where used in construction materials for enclosed structures.[2]

TABLE 1

Typical Bauxite Analyses

	Jamaican %	Surinam %	Arkansas %	European %
Al_2O_3				
Gibbsite	38	52.5	40	
Boehmite	9			53
Kaolinite, etc.	2	3	10	4
Fe_2O_3	20	9	8	24
SiO_2	2.5	3.5	12	5
TiO_2	2.5	2.5	3	2
Minor Constituents	1.0	0.5	1	0.5
Loss on ignition	25	29	26	11.5

TABLE 2

Alumina Production Plant
Specific Radionuclide Data[3]

Sample	Radium-226	Uranium-234	Uranium-235	Uranium-238	Remarks
Mississippi River Intake Water pCi/L	---	---	---	—	Gross alpha 1.7 Gross Beta 3.5
Bauxite Ore pCi/g	4.7 ± 0.4	4.8	0.18	4.9	
Gypsum pCi/g	0.27 ± 0.07	0.41	0.01	0.33	
Separator Sand pCi/g	7.2 ± 0.49	3.0	0.30	2.8	
Red Mud Slurry					
Dissolved solids pCi/L	0.52 ± 0.14	3.5	.045	3.5	
Suspended solids pCi/g	20 ± 0.7	13.0 ± 0.8	1.0 ± 0.2	14 ± 0.8	

Errors expressed represent 2 σcounting errors based on a single sample survey.

TABLE 3

BAUXITE PROCESSING

RADIONUCLIDE CONCENTRATION (pCi/g)[4]

MATERIAL	^{234}U	^{235}U	^{238}U	^{230}Th	^{232}Th	^{228}Th	^{226}Ra	^{210}Pb	^{210}Po
BAUXITE ORE*	6.6 ± 0.6	0.28 ± 0.07	6.8 ± 0.6	7.8 ± 2.5	8.2 ± 2.6	7.8 ± 2.5	8.0 ± 1.7	8.3 ± 0.7	8.5 ± 0.8
BLENDED BAUXITE**	4.0 ± 0.5	0.16 ± 0.04	4.0 ± 0.5	3.5 ± 0.03	5.2 ± 1.2	5.6 ± 1.2	4.4 ± 1.3	5.3 ± 0.4	4.2 ± 0.5
ALUMINA KILN FEED	0.07 ± 0.03	< 0.02	0.05 ± 0.03	< 0.05	< 0.05	< 0.05	0.08 ± 0.05	0.20 ± 0.15	0.00 ± 0.20
ALUMINA PRODUCT	0.32 ± 0.07	0.06 ± 0.03	0.31 ± 0.07	< 1.0	< 0.02	< 0.2	0.21 ± 0.05	< 1.4	< 0.54
RED MUD	7.5 ± 1.2	0.30 ± 0.08	7.5 ± 1.2	5.1 ± 1.3	6.0 ± 1.5	6.3 ± 1.5	6.5 ± 2.0	7.6 ± 0.4	7.7 ± 1.7
PREPARED SINTER MUD***	4.7 ± 0.5	0.18 ± 0.04	4.8 ± 0.5	4.2 ± 1.1	5.0 ± 1.3	5.5 ± 1.4	3.9 ± 1.2	6.8 ± 0.4	4.6 ± 0.5
SINTER	6.6 ± 0.9	0.42 ± 0.08	6.4 ± 0.8	6.5 ± 1.6	9.2 ± 2.1	8.6 ± 2.0	3.9 ± 1.2	3.6 ± 0.4	3.2 ± 1.2
BROWN MUD	5.6 ± 0.5	0.33 0.27	5.5 ± 0.4	8.0 ± 2.7	13.0 ± 3.8	13.0 ± 3.8	5.6 ± 1.2	5.7 ± 0.8	5.4 ± 0.7

* ARKANSAS ORE
** BLENDED ARKANSAS AND SOUTH AMERICAN ORE
*** INCLUDES ADDED LIMESTONE

Errors expressed represent 2σ counting errors based on a single sample survey.

BASIC FLOW DIAGRAM

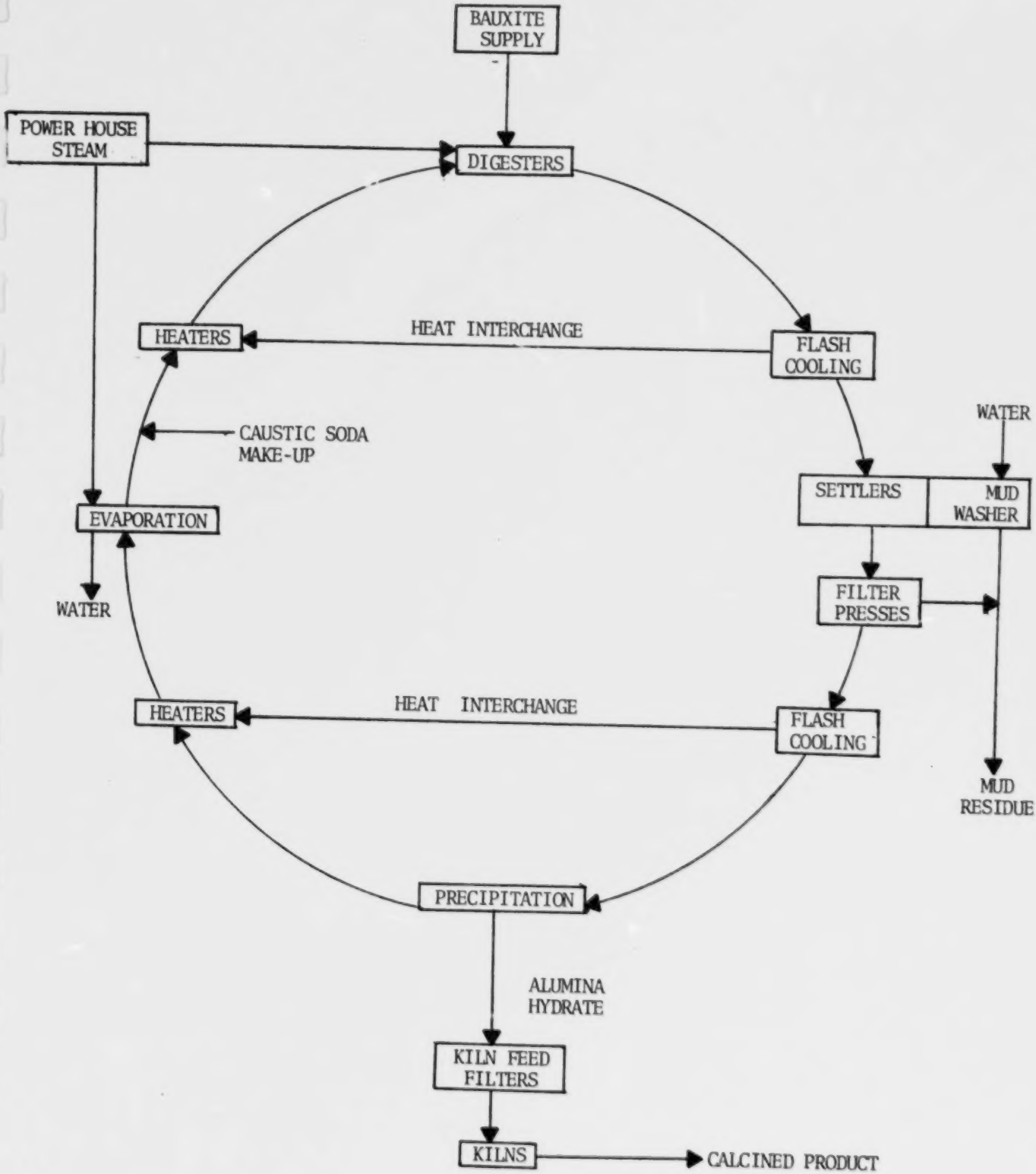


Figure 1

REFERENCES

1. Industrial and Engineering Chemistry - Vol. 47, Nos. 9, 10, pp. 1672-1681, pp. 2066-2072, 1975.

2. Kaiser Aluminum and Chemical Corporation, Baton Rouge, LA, personal communication, 1979.

3. Radionuclide analysis furnished courtesy of Eastern Environmental Radiation Facility, USEPA, Montgomery, Alabama.

4. Donald W. Hendricks, Director, ORP Las Vegas Facility, USEPA, Las Vegas, NV. Private Communication.

RADIOACTIVITY ASSOCIATED WITH COLUMBIUM-TANTALUM

Radioactivity from both the thorium and uranium decay chains is known to be associated with production of columbium (also known as niobium) and tantalum. The U. S. relies principally on imported ores, ferrocolumbium, and tin slags for its columbium and tantalum production. Ores are imported primarily from Brazil, Nigeria, Canada, Zaire, Malaysia, and Australia. Slags are imported mainly from Thailand, Brazil, Malaysia, Nigeria, and Zaire. Thorium content of the monazite fraction of these ores averages 3-4 percent. Tin ore from Nigeria is reported to contain an average of 0.4 percent of equivalent ThO_2. Pyrochlore ore (a source of columbium and tantalum) from Rhodesia, Kenya, and Uganda ranges from 1 to 3 percent ThO_2[1].

Pyrochlore ore from Nigeria was reported to contain 41.1 percent columbium-tantalum oxide, 3.1 percent uranium oxide, and 3.3 percent thorium oxide. Uranium and thorium have also been reported in association with columbium and tantalum ores in Canada. Euxenite ore from Ontario assayed 0.35 to 0.54 percent uranium, 2.5 to 4 percent thorium, 4 to 6 percent columbium, and 0.8 to 2 percent tantalum[2].

The minerals tantalite (up to 84 percent Ta_2O_5) and columbite (up to 77 percent Cb_2O_5) supply most of industry's needs for tantalum and columbium. Tantalite and columbite are usually found as opaque iron-black or brownish colored minerals and can be rich in iron and manganese content.

Pyrochlore is a complex columbium mineral containing calcium and sodium with variable amounts of iron, titanium, rare earth metals, fluorine and sometimes uranium. It is commonly brown or yellow, but its color is quite variable.

Microlite is the tantalate equivalent of pyrochlore and was mined in New Mexico in World War II[3].

In 1974, U. S. columbium and tantalum processing companies were located in Illinois, Pennsylvania, New York, Oklahoma, Michigan, Missouri, Ohio, South Carolina, Massachusetts, New Jersey, and Oregon[4].

United States imports for consumption of columbium and tantalum mineral concentrates were 1,961 tons in 1973 and 2,513 tons in 1974.

REFERENCES

1. Minerals Yearbook, U. S. Department of Interior, Washington, D.C., U. S. Government Printing Office, 1956.

2. Minerals Yearbook, U. S. Department of Interior, Washington, D.C., U. S. Government Printing Office, 1955.

3. Tantalum and Niobium by G. L. Miller, 1959, Academic Press, Inc., New York.

4. Minerals Yearbook, U. S. Department of Interior, Washington, D.C., U. S. Government Printing Office, 1974.

MINERAL WOOL

Mineral wool is a fibrous, wool-like material used principally for non-flammable, thermal insulation. The three basic types of mineral wool are rock wool, slag wool, and glass wool. The wool is usually manufactured by blowing air or steam through molten material to create fibers. The molten material can also be created by discharging centrifugally or through subdividers to create the fibers. The molten material is composed of various combinations of minerals and/or slag. The fibers can then be formed or used as loose wool, granulated wool, batts, felts, blankets, blocks, boards, pipe insultation, acoustical pads or boards, insulating cements, roofing, gaskets, sound proofing material, abrasives, coating for structural materials, blotting paper, and mulch.[1]

Mineral wool was made in Wales as early as 1840. Slag wool was first made in Germany in 1870. Glass wool was also developed initially in Germany. In the U. S., the rock wool industry was established in Indiana by 1897. Early U. S. production of mineral wool products grew from 6,002 short tons in 1900 to 142,393 short tons in 1935. By 1945 (the last year tonnages were reported in the Minerals Yearbook), production had increased to about 720,000 short tons per year.

Glass wool (or glass silk) has the composition of soda-lime glass. Slag and rock wools are manufactured using a wide variety of slag or rock types depending in part on the individual plant, its location, and the availability and cost of raw materials. Plants making slag wool have either used or at least pilot tested slags of iron, phosphate, copper, and lead. A number of minerals have been used, tested, proposed, or patented for use in manufacture of rock wool. Among these minerals are volcanic ash, wollastonite, kyanite, bauxite, metaanthracite (bituminous coal), traprock, dolomite, limestone, slate, granite, and unspecified Florida minerals.[1]

In 1939 there were at least 60 U. S. companies operating 70 or more plants with a production capacity of about 600,000 short tons per year. At least 19 states have had operating plants.

Extensive use of mineral wools in the U. S. for home insulation began about 1927. Since that time the fraction used for home insulation compared to other uses has varied from year to year but has generally been in the 30-70% range (probably through 1960).

Because of the use in mineral wool manufacture of raw materials known to contain levels of natural radioactivity elevated above background, the Las Vegas Facility of the USEPA Office of Radiation Programs has performed radiochemical analysis on several samples of mineral wool and of some of the input raw materials. Some of this data was reported at the 11th Annual Conference on Radiation Control, May 7, 1979.[2] Results of the radiochemical analyses are summarized in Table 1.

TABLE 1

Mineral Wool Radioactivity Content

Material	Radium-226 Content (pCi/g)	Remarks
Slag Wool (Blowing Type)	16.0 ± 0.73	Made with phosphate slag, steel slag, coke, and basalt.
Slag Wool (R-19 Blanket Type)	13.0 ± 0.67	Made with phosphate slag, steel slag, coke, and basalt.
Slag Wool (Blowing Type)	2.8 ± 0.29	Made with steel slag, coke, and basalt.
Phosphate Slag (Rock)	38.0 ± 1.1	
Phosphate Slag (Ground)	47.0 ± 1.2	
Steel Slag	2.9 ± 0.30	
Coke	0.51 ± 0.13	
Basalt	0.56 ± 0.14	
Slag or Rock Wool	6.6 ± 0.44	Believed made with steel slag.
Slag or Rock Wool (Spun)	5.5 ± 0.41	
Glass Wool (Blowing Type)	0.50 ± 0.13	
Glass Wool (R-19 Batt)	0.41 ± 0.12	

Errors expressed represent 2 σ counting errors based on a single sample survey.

References

1. Minerals Yearbooks, U. S. Bureau of Mines. U. S. Department of Interior. Annual Publications 1933-1960.

2. Haars, Ellen. NORM Studies in the State of Washington. 11th Annual Conference on Radiation Control. May 7, 1979. Oklahoma City, Oklahoma.

PHOSPHATE SLAG - CONSTRUCTION USE

Many mineral extraction industries are known to have elevated levels of naturally occurring radionuclides associated with the ores. Depending on the particular industry and extraction process, the radioactivity content of the ore may go with the product, with the wastes, or be distributed between the product and wastes. One mineral industry of current concern because of the radioactivity content of its waste (or byproduct, depending on definition) is the elemental phosphorus industry. Phosphate ore is treated in a thermal process plant by heating in electric furnaces to produce elemental phosphorus and residues of slag and ferrophosphorus. Most of the radioactivity in the ore remains with the slag with less than 1 percent going to the elemental phosphorus or ferrophosphorus[1]. Concentration of radium-226 in the slag varies with ore origin but ranges from about 17 to 60 picocuries per gram with Tennessee ores having typically the lowest radioactivity content. Florida, Idaho, and Montana ores and slags are usually in the 40 to 60 picocurie per gram range.

Production of elemental phosphorus by the electric furnace process began in the United States at the Oldbury Electrochemical Company (later Hooker Chemical Company) plant in Niagara Falls, NY, in 1896. Elemental phosphorus has been produced continuously in the U.S. since that time. Operating elemental phosphorus plants have ranged in number from one to twelve operating in any given year depending on demand.

While there seems to be no readily available list of operating plants, Hendricks,[2] based on U.S. Bureau of Mines Mineral Yearbooks publications, has estimated that there have been about 23-25 plants in operation during the 1896-1975 time frame. Additional plants are projected for construction during future expansion of the southeastern Idaho phosphate industry. While total production figures for

phosphate slag are also not readily available, Hendricks estimated (based on ferro-phosphorus production) that slag production through 1975 may have been on the order of 200-400 million tons. This is about twice the total tonnage of uranium mill tailings in the U.S. On a radioactivity per ton basis, however, uranium tailings will contain 10 times or more radioactivity per ton as will the slag.

Phosphate slag, which is predominantly calcium silicate, has been widely used for many years as a construction material. In the Idaho and Montana area it has been used extensively as aggregate in concrete and asphalt as well as for railroad ballast, casting material alongside highways, roadbed fill, backfill, farm road gravel, and stabilization material for stock yards. It has been used in construction of streets, highways, sidewalks, parking lots, school playgrounds, schools, churches, homes, and public buildings. Many of these same uses have been found in other parts of the country. In Florida slag has been used on roofs and in septic tile fields. Slag has also been used in the manufacture of rock wool insulation and proposed for use in manufacture of ceramic tile.

Many of these uses can cause increased radiation exposure to people living or working near the slag-bearing materials. Exposure is principally from direct gamma radiation emitted from the radionuclides contained in the slag or from airborne radionuclides arising from release and decay of radon gas.

Some slag has also been used as a soil liming agent or as a filler for fertilizer. The exposure pathway for these uses would probably be indirect through ingestion of food crops grown on land where the material had been used. Inhalation of slag dust originating from street or road traffic is also a possible exposure pathway.

U.S. EPA studies of the national phosphate industry began in June 1974. Initial studies were directed toward mining and processing sites. Studies are now being conducted in Montana, Idaho, and Alabama to determine radiation exposure levels in

homes and other structures where phosphate slag has been used. A program to measure gamma exposure and radon progeny levels in selected structures began in 1975 in Idaho, in 1978 in Montana, and in 1979 in Alabama. Because of limited EPA resources, most of these latter studies are being conducted by State personnel utilizing EPA equipment.

A mobile gamma scanning van developed by EPA's Office of Radiation Program-Las Vegas Facility was used in 1977 in Soda Springs and Pocatello, Idaho, to identify locations in the communities where phosphate slag had been used.[3] In 1978, the van was used for the same purpose in Anaconda and Butte, Montana and in Twin Falls and Pocatello, Idaho. The 1977 Pocatello survey was only able to cover about three-quarters of the community because of other commitments.

In these communities, the van identified the approximate numbers of anomalous locations shown in Table 1.

TABLE 1

Number of locations having anomalous levels of gamma ray emission rates

Community	Number of Locations
Pocatello, Idaho	2035
Soda Springs, Idaho	370
Twin Falls, Idaho	33
Butte, Montana	750
Anaconda, Montana	Primarily in streets. State will survey on foot.

These anomalous locations are sites where the van equipment indicates elevated gamma ray emission rates. The equipment cannot differentiate whether the elevated emission rate is due to slag or to some other source of natural radioactivity. The van

is used essentially as a screening device to indicate the size of the problem and to identify specific sites which can then be checked more closely. (Measurements with the van were complicated by the widespread use of slag in streets, sidewalks, planters, and driveways.) Once the sites are identified, they can be visited by monitoring teams to identify the source of radioactivity and to measure the levels of radioactivity on the site.

Assuming that the slag use is in a structure, the monitoring team usually makes indoor measurements of gamma radiation and takes an air grab sample to measure radon progeny levels. Because of the wide variability of radon and progeny levels (even in a house with no abnormal levels of radionuclides in the construction materials), long-term air sampling is usually necessary in order to obtain a yearly average air concentration. Radon and progeny levels will vary with ventilation rate, soil moisture, barometric pressure, air temperature as well as from basement to upper floors. Variations can range by a factor of ten or more in a single day.

Background gamma ray exposure rates measured by EPA and State personnel in Butte in 1978 averaged about 18 microroentgens per hour (μR/hr). Exposure rates measured at one meter above Butte streets where slag had been used in pavement averaged about 34 μR/hr or about 16 μR/hr above background. Background in Anaconda was about 13 μR/hr. In 1977 measurements in Pocatello indicated background levels to be about 11 μR/hr while levels as high as 40 μR/hr were measured at one meter above road surfaces. Background in Soda Springs was about 15 μR/hr. Exposure rates as high as 100 μR/hr were measured indoors in Soda Springs in a church where slag had been used. In homes using slag, levels ranged up to 65 μR/hr (including background). Most of the slag structures in Soda Springs seemed to be in the range of 20 to 40 μR/hr (indoors) including background.

Data on background levels of radon progeny in structures throughout the United States is limited but suggests a range of about 0.0001 to 0.005 working level (WL) with

an average of about 0.002 WL.[4] Only limited long-term progeny sampling data is available so far. Two residences containing slag in Soda Springs sampled during the 1975-1977 time frame averaged 0.010 WL and 0.014 WL (including background). Two other slag residences sampled for shorter time periods averaged 0.015 WL and 0.016 WL (including background).

Residences in Butte are also being sampled. In Butte, however, while elevated progeny levels have been measured in a number of structures, the source of the radon and progeny is not clearcut. Some of the Butte structures which were sampled because they did not contain phosphate slag and were thought to be representative of background had higher progeny levels than some of the slag structures. The cause of this anomaly has not been fully resolved but it appears that some of the structures with elevated levels may have been built with slags from other industries (i.e., copper slag and manganese slag). These slags also contain naturally occurring radionuclides but in lesser (about one fourth) quantities than the phosphate slag. Some of the structures have no apparent cause for the elevated levels but it has been conjectured that the radon is originating below the ground surface and is perhaps coming from fissures or cracks extending toward the underground mines which underlie the community.

Outdoor radon levels in Butte also appear to be increased with respect to other communities. This is probably due in large part to the heavily mineralized area together with contributions from mine exhausts and large mineral waste piles. These increased outdoor radon levels, while not the sole explanation for the increased indoor radon progeny levels, would certainly contribute to the increase.

The limited studies thus far have shown that there is a clear need for further investigation in this area. Large numbers of people are being exposed to low levels of ionizing radiation. The source of this radiation and the exposure levels are not well

understood. Based on early results, Idaho has prohibited use of phosphate in construction of structures but continues to permit its use in highway and road construction. In Montana use of slag in structure construction has also been stopped. Other uses are licensed by Montana.

Further study is necessary to determine the exposure levels and health risks associated with the use of these low level radioactive wastes. If it is deemed that these wastes constitute an unacceptable health risk, then it will be necessary to determine reasonable remedial actions that can be taken to lower the exposure levels to reduce the risk. For those cases where elevated exposures exist without an immediately obvious source, it may also be necessary to do sufficient work to identify the source.

References

1. U. S. Environmental Protection Agency, "Radiological Surveys of Idaho Phosphate Ore Processing - The Thermal Process Plan." November 1977. Technical Note ORP/LV-77-3.

2. Hendricks, D. W. Private communication. February 1979.

3. Hans, J. M. et al. "Above Ground Gamma Ray Logging for Locating Structures and Areas Containing Elevated Levels of Uranium Decay Chain Radionuclides." April 1978. Technical Note ORP/LV-78-2.

4. Guimond, R. J., et. al. "Indoor Radiation Exposure Due to Radium-226 in Florida Phosphate Lands." February 1979. EPA 520/4-78-013.

UNITED STATES URANIUM PRODUCTION

In recent years, United States uranium production has begun to shift away from almost 100 percent conventional open pit and underground mining toward other types of production.[1] Both underground and open pit mining produce ore which is processed through conventional acid or alkaline leach mills. Other sources of uranium production are heap leaching, ion exchange production from copper or uranium mine water, in situ leaching from underground ore bodies, processing of low grade stockpiles, and production from other mineral extraction industries such as phosphate and beryllium. Extraction of uranium from seawater is also being investigated.

U. S. uranium production facilities operating as of January 1, 1980, are shown in Table 1 and in Figure 1.

Average ore grade* in conventional milling has dropped from about 0.23 percent in 1967 to about 0.11 percent in 1979.* The average radium-226 and thorium-230 content of the tailings has therefore dropped from about 640 pCi/g to about 300 pCi/g. On the other hand, the amount of waste tailings generated to produce the same amount of uranium has doubled. Ore grade at at least one mill is less than 0.05 percent (See Figure 2).

*Two pounds of U_3O_8 per ton of ore is equivalent to an ore grade of 0.1 percent.

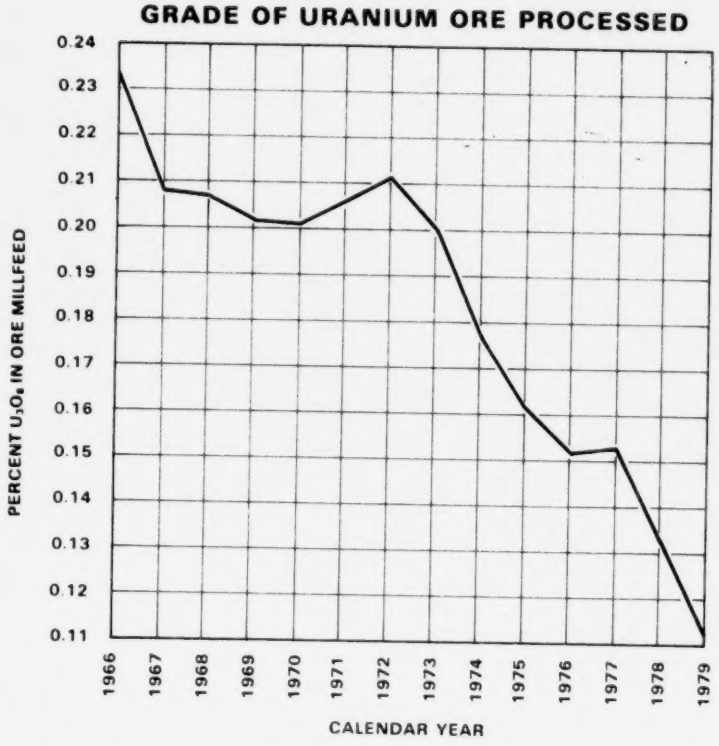
U.S. URANIUM PRODUCTION MILLS
Operating as of 1/1/80

Conventional Mills	Plant Location	Nominal Capacity (Tons Ore/Day)	Nominal Capacity (Tons U_3O_8/Year)
ANACONDA Copper Company	Grants, New Mexico	6,000	
Atlas Minerals Corporation	Moab, Utah	1,400	
Bear Creek Uranium Company	Powder River Basin, Wyoming	2,000	
Chevron Resources Company	Hobson, Texas	2,500	
Conoco-Pioneer Nuclear	Falls City, Texas	3,400	
Cotter Corporation	Canon City, Colorado	1,200	
Dawn Mining Company	Ford, Washington	450	
Exxon Minerals Company, USA	Powder River Basin, Wyoming	3,200	
Federal-American Partners	Gas Hills, Wyoming	950	
Kerr-McGee Nuclear Corporation	Grants, New Mexico	7,000	
Pathfinder Mines Corporation	Gas Hills, Wyoming	2,500	
Pathfinder Mines Corporation	Shirley Basin, Wyoming	1,800	
Petrotomics Company	Shirley Basin, Wyoming	1,500	
Rio Algom Corporation	La Sal, Utah	750	
Sohio-Reserve	Cebolleta, New Mexico	1,600	
Union Carbide Corporation	Uravan, Colorado	1,300	
Union Carbide Corporation	Natrona County, Wyoming	1,400	
United Nuclear Corporation	Church Rock, New Mexico	3,000	
United Nuclear—Homestake Partners	Grants, New Mexico	3,400	
Western Nuclear, Inc.	Jeffrey City, Wyoming	1,700	
Western Nuclear, Inc.	Wellpinit, Washington	2,000	
	Total	49,050	19,000-21,000
Solution Mining Operations	**Plant Location**		
Everest Mineral Corporation	Hobson, Texas		
IEC Corporation	Three Rivers, Texas		
Mobil Oil Corporation	Bruni, Texas		
Union Carbide Corporation	Palangana, Texas		
United States Steel Corporation	George West, Texas		
U.S. Steel-Niagara Mohawk	George West, Texas		
Uranium Resources, Inc	Bruni, Texas		
Wyoming Mineral Corporation	Bruni, Texas		
Wyoming Mineral Corporation	Three Rivers, Texas		
Wyoming Mineral Corporation	Irigaray, Wyoming		
	Total		1,200-1,600
Phosphoric Acid Byproduct	**Plant Location**		
Freeport Uranium Recovery Corporation	Uncle Sam, Louisiana		
Gardinier, Inc.	Tampa, Florida		
Uranium Recovery Corporation	Mulberry, Florida		
Wyoming Mineral Corporation	Pierce, Florida		
	Total		500-700
Heap Leaching:			
Dumps, Tailings, or Copper Dumps	**Plant Location**		
Durita Development Corporation	Naturita, Colorado		
Solution Engineering, Inc.	Falls City, Texas		
Union Carbide Corporation	Maybell, Colorado		
Wyoming Mineral Corporation	Bingham Canyon, Utah		
	Total		100-300
	Grand Total	49,050	20,800-23,600

Table 1

URANIUM MILLS IN THE UNITED STATES OPERATING AS OF 1/1/80

Figure 1


GRADE OF URANIUM ORE PROCESSED
PERCENT U_3O_8 IN ORE MILLFEED
0.24
0.23
0.22
0.21
0.20
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
CALENDAR YEAR

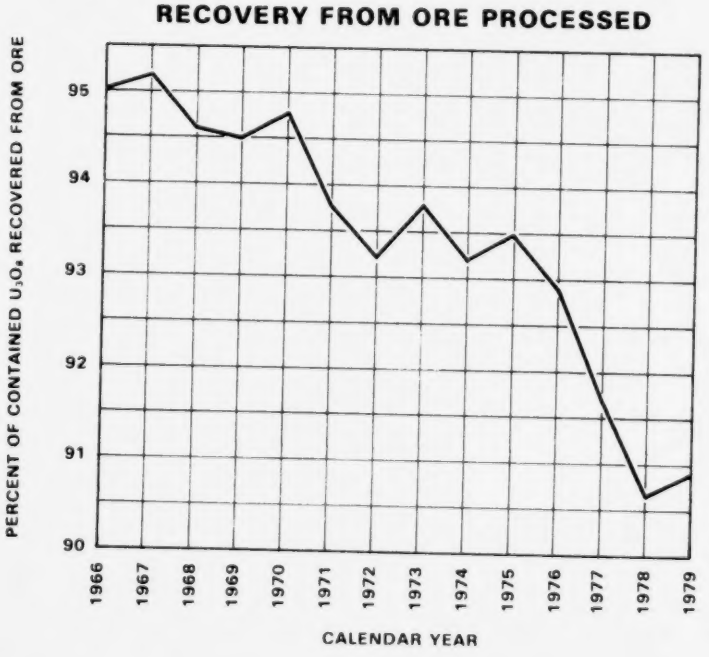

RECOVERY FROM ORE PROCESSED
PERCENT OF CONTAINED U_3O_8 RECOVERED FROM ORE
95
94
93
92
91
90
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
CALENDAR YEAR

Figure 2

References

1. Statistical Data of the Uranium Industry, GJO-100 (80), January 1, 1980, U. S. Department of Energy, Grand Junction Office, Colorado.

RECOVERY OF URANIUM FROM WET-PROCESS PHOSPHORIC ACID PLANTS

There are several potential problem areas relative to uranium recovery from phosphoric acid that deserve attention by State radiation control personnel. There are three types of recovery operations modeled in a report entitled, ORNL/EPA-2 "Potential Radiological Impacts of Recovery of Uranium from Wet-Process Phosphoric Acid", January 1979. Model number three produces UF_4 (green salt) as the final product whereas the other two models produce U_3O_8. All of the thorium is brought on through the process and is contained in the green salt. The inhalation of the thorium isotopes becomes very significant, with doses to the bones higher than that from uranium isotopes by a factor of 260. Computer models of this case (plant model 3) predict bone doses to maximally exposed individuals of 240 mrem/year at a production rate of 1000 metric tons uranium (MTU)/year. This individual is located 0.5 mile downwind of the site. This dose can be reduced to 0.1 mrem/year by the proper installation of a HEPA filter, a reduction of a factor of 2400.

It is recommended that this filter or a suitable system be required on all plants of this type, as this should be well within the resources of any of these operations in order to enable them to operate in a manner to keep exposure to ALARA, without unreasonable cost.

Facilities of the type resulting in the U_3O_8 product are in operation and measurements of various kinds have been made by Oak Ridge Associated Universities. Apparently some contamination from phosphoric acid spillage has occurred. This indicates that an effort should be made to prevent and mitigate the consequence of accidents. The radioactive materials license for these facilities should require an emergency response plan that delineates responsibilities. Measurements relative to

these facilities indicate the potential for significant airborne releases. Atmospheric release of particulate U_3O_8 from both the room ventilation fans and stack is evident. The average concentration of natural uranium released from the stack was 3.42×10^{-12} μCi/ml. However, this is at a production rate of 50 MTU/year. The facility is licensed to produce 900 MTU/year, and according to the report, the release from the stack should increase proportionally.

Much more significant than the stack release however, is the injection of airborne U_3O_8 into the environment by the room ventilation fans where releases were 47×10^{-12} μCi/ml at 50 MTU/year production rate. At 900 MTU/year production rate, this would be 18 times greater, or 8.5×10^{-10} μCi/ml, 170 times greater than the maximum permissible concentration in air for an individual of the general public. Using a χ/Q calculation, at a production rate of 1000 MTU/year and worse case meteorological conditions (wind at 2 meters/sec, Pasquill category F, gives 1.8×10^{-10} μCi/ml at the fence line which is greater than the maximum allowable concentration for release to an offsite environment. (Drumming building to fence line distance is about 50 meters.) The release is about 25000 grams/year (50 MTU/year production); at 900 MTU/year production this would increase to 4.5×10^5 grams/year.

This airborne release to the environment may be reduced considerably by installation of HEPA filters to the roof mounted ventilation fans. It would seem prudent to require proper filtration on all such fans on drumming rooms in future recovery operations.

Plans should be established by the States, the recovery facilities and the transportation companies, to react to a transportation accident involving the distribution into the environment of either the concentrated acid from the first step in the recovery process, or the final product (U_3O_8 or UF_4). The acid concentrate contains about 8.5 grams of uranium per liter of acid. There will be four to six truck loads per

day per module, with each load consisting of about 15 short tons of liquid. The risk of an accident appears to be low. However, if an event does occur that releases radioactive material into the environment, the potential for pollution of streams is high, especially in states like Florida where there exists a drainage ditch beside almost every road.

In spite of assurances and statistical studies indicating a low probability of such an accident, at least three accidents involving yellow cake have already occurred. In two cases, trucks carrying yellow cake did turn over and some drums did release their contents to the environment. The spills were cleaned up at considerable costs with some confusion as to what role various parties were to play. Therefore, contingency plans should be developed and implemented. The plans should clearly delineate the roles and responsibility of concerned parties - state, local, shipper, transporter, consignee, NRC and DOE.

Solid and liquid contamination of off-site areas should remain at low levels barring a catastrophic accident such as a tornado, explosion, fire or transportation accident. The phosphoric acid is returned to fertilizer production. There may be some loss of solvents such as kerosene, ammonia, etc., but these are not addressed here. Other debris are of small magnitude compared to gypsum piles.

In conclusion, the recovery of uranium from wet process phorphoric acid plant processes is desirable, and should be encouraged. Conversely however, to operate in any mode but one containing the philosophy of ALARA, particularly when effective control technology is well within the industry's resources, would not be in the best interest of the population. The unknown quantities of radon and daughter releases from huge gypsum piles, combined with increased gamma levels and radium in water, should be taken into account when any additional exposure pathway is proposed.

It would be advisable to do further studies on these additional pathways; perhaps, a study of the integrated phosphate-uranium industry should be undertaken as suggested in ORNL-EPA-2.

In summary, the Committee recommends that operation of uranium recovery facilities at phosphoric acid plants include the following:

1. HEPA filters or other suitable collection system on all ventilation discharges including drumming rooms.
2. Adequate continuous air monitor on all ventilation discharges.
3. Air monitoring at the fence line.
4. Establishment of a thorough pre-operational environmental surveillance baseline program.
5. Periodic soil monitoring during the operating life of the plant.
6. Development of general release criteria for facilities, to be applied upon abandonment.

TAPE DISPENSER BALLAST

Introduction

Zircon sands have been used in the manufacture of cellophane tape dispensers as ballasts. This report covers the results and some conclusions on the radioactive nature of tape dispenser ballast.

NOTE: This interim report only involves the ballast from a single model from one of the manufacturers of tabletop tape dispensers. There is known to be at least one other manufacturer using zirconium sands.

The analysis consisted of:

A. Gamma exposure vs. distance

B. Alpha, beta vs. distance

C. Isotopic analysis on GeLi spectroscopy

Gamma Exposure[1]

An experiment was conducted using NaI portable gamma scintillator and one tape dispenser.

Table 1

Distance (in)	0	1	2	3	6	12	18	24	36	48
Exposure Rate (μR/hr)	22	12	11	8	6	5	5	4	5	4

The average background was 4-5 μR/hr, and was read with tape dispenser 120 inches away. The background at three feet and two feet are essentially equal.

The Committee evaluated the exposure rate and found it to be about 0.3 μR/hr at two feet. This measurement was performed within a heavily shielded containment. The Committee performed a second evaluation within a heavily shielded containment and found the exporate rate to be 0.3 μR/hr.

Alpha-Beta Exposure

An experiment was conducted using a GM instrument with a thin-end window (1.5-2.0 mg/cm^2) probe. The dispenser was placed on side with the rubber sole removed.

Table 2

Distance (in)	0	1	2	3	4	5	6	12
Counts/min	104	68	55	44	29	32	33	12

NOTE: At contact, the window is 1/8 inch away from ballast (tube recessed in holder); with sole (1/8 inch foam rubber) in place, the alpha-beta remains at 12 c/m all the way to contact.

Gamma Radionuclide Analysis[2]

A 50 minute count on the GeLi spectroscopy system set at 2 KeV per channel, 1024 channels, was conducted on 1464 grams of the ballast material. The result is given in pCi/gram and pCi/dispenser (700 grams).

Table 3

Isotope	pCi Per Gram	pCi Per Dispenser
U 238	38.6 ± .05	27000
Ra 226*	65.5 ± .07	46000
Pb 214	42.1 ± .02	29000
Bi 214	44.6 ± .02	31000
Th 232	27.2 ± .05	19000
Ra 224	25.0 ± .10	18000
Pb 212	22.8 ± .14	16000
Bi 212	22.8 ± .14	16000

*May include gamma from U-235

Errors are 2σ counting errors.

Estimated Annual Dose

Based upon the Task Force findings, the annual dose from 0.3 μR/hr (40 hour work week, 52 week year) could be 0.6 mR/year above background. Observation of the variability of background shows this dose to be less than dose variance due to the variability of background exposure.

Conclusion

The findings of the above mentioned experiments yields the conclusion that the tape dispensers do not present themselves as a significant health hazard in everyday use. The small gamma exposure offered by these devices may be partially shielded by the table and attenuated by distance. However, the Committee concludes that the use of zircon sand as weight in tape dispenser results in unnecessary radiation exposure which could be avoided by the use of a less radioactive ballast materiel. It should be mentioned the manufacturer of the model tested no longer uses radioactive sands for ballasts.

FOOTNOTES

1. Gamma exposure measurement performed by Task Force 7 members, Baton Rouge, LA, 1979.

2. Isotopic analysis performed by Florida Department of Health and Rehabilitative Services, Orlando Radiological Laboratory, 1979.

OIL PRODUCTION BRINES

The occurence of environmentally high concentrations of radium isotopes in oil field production waters (also called oil field brines, produced water, produced wastewater, or formation water) is well documented (Kuroda, 1953; Gott and Hill, 1953; Armbrust and Kuroda, 1956). Radium-224, radium-226, and radium-228 in production waters from oil fields in Oklahoma and Arkansas, with activities ranging from 100-1100 pCi/l radium-224, 1-1600 pCi/l radium-226, and up to 400 pCi/l radium-228 have been reported. In addition, 8 pCi/l for thorium-228 and 0.5 pCi/l for thorium-227 have also been reported from well samples. Environmentally high concentrations of lead-210 precipitates collected from the bottom of oil-water separators, and from ditches and ponds used for disposal of the production water have been found.

The Mississippi, Louisiana, and Texas Gulf Coasts are becoming the major oil-producing areas of the United States. Texas and Louisiana have numerous producing wells both on- and off-shore. During the period November, 1972 to October, 1973, approximately 1.7×10^{10} liters of production water were discharged to the Gulf of Mexico from operations on the Federal Outer Continental Shelf (OCS) leases outside the three-mile limit (data furnished by U. S. Geological Survey, 1974). Records of discharges inside the three-mile limit and on-shore are maintained by the states in which the discharges occurred. Data provided by the Office of Conservation, State of Louisiana, shows that for the year 1975, a state total of 8.1×10^{10} liters of formation waters were discharged into the surface environment, 17.5% off-shore and 82.5% or 6.7×10^{10} liters on-shore. Of the latter, 6×10^{10} liters were discharged into non-potable water bodies, 4.3×10^{9} liters were discharged into streams and rivers, and 2.4×10^{9} liters were disposed of in open holding pits from which gradual loss occurs via evaporation and seepage into the underlying ground.

For purposes of comparison, it is noted that the average open ocean surface waters contain about 0.05 pCi/l; coastal waters probably do not generally get much higher than about 1 pCi/l, except in very restricted environments; drinking water standards restrict the permissible radium-226/radium-228 to less than 5 pCi/l; and Agreement State-NRC regulations governing the operations of licensees permit not more than 30 pCi/l of radium-226 in liquid discharges to unrestricted access areas. Production waters currently do not fall under these regulations, but it is notable that they contain many times the permissible regulated inputs. The impact of the Resource Conservation and Recovery Act of 1976 is unknown at this time.

Unknown at this point is the ultimate fate of such naturally occurring radium being discharged into local estuarine environments (marshes, streams, rivers). It is also unknown at this time whether other isotopes of the uranium-thorium series are present in environmentally significant concentrations in the production waters. Recommendations by the Committee concerning uncontrolled discharges of these brines will be delayed pending results of other on-going studies, from which additional information and data are expected.

TITANIUM ORE PROCESSING

The titanium industry has two principal products, titanium dioxide and titanium metal.

The most common titanium ores are rutile, ilmenite, leucoxene, and anatase.[1] Other lesser titanium sources are titanium slag, titaniferous iron ore, sphene, Perovskite, Brookite, and magnetite.

Iron percentages in titanium ores can range from a fraction of a percent (rutile) to as much as 55 percent (ilmenite). Weathering of ilmenite causes oxidation and leaching of the iron content with a final product of almost pure titanium dioxide known as leucoxene. Compositions of some of the more common ores are shown in Table 1.

Much of the ore originates in beach and fluvatile sand deposits which also contain monazite. The monazite in turn contains uranium and thorium decay chain radionuclides. The monazite content of the deposits (and therefore uranium and thorium chain content) varies from location to location. The monazite content of the titanium ore fraction depends on how well the monazite has been removed before shipping from the mine. Titanium processing facilities which have operated for many years would be expected to have older wastes with higher levels of radioactivity than newer facilities.

Titanium metal is currently produced in the U. S. primarily using rutile and leucoxene from Australia. Titanium pigment is produced principally from rutile, anatase, ilmenite, and slag.[2, 3]

Titanium metal is produced by chlorination of rutile, blends of rutile with leucoxene, or of other concentrates with high titanium dioxide content. The chlorination process is a modified Kroll process (similar to the process used in

zirconium production). The titanium chloride is reduced with magnesium or sodium to titanium sponge which is subsequently converted to ingots.[2] See Figure 1.

Titanium dioxide pigments are made either by a chlorination process or by an older sulfate process. High TiO_2 content ores (rutile, or ilmenite and rutile substitutes) in the chloride process are converted to volatile chlorides. Titanium dioxide is then recovered by vapor phase oxidation of $TiCl_4$.

In the sulfate process, lower TiO_2content ilmenite or slag is converted to water soluble sulfates. Titanium dioxide is recovered by hydrolysis of high titanium oxide solutions. Titanium dioxide pigments have been produced in the U. S. since 1918 using the sulfate process. This process was used exclusively until the 1950's when the chlorination process was introduced. (See Figure 2.)

Large quantities of wastes are generated during the production of titanium dioxide. In 1972 domestic titanium dioxide plants produced about 1.7 million metric tons of iron-acid sludge and 146 thousand metric tons of iron-chloride sludge.[1] Most of the radioactivity associated with the incoming ores would be expected to go with these wastes. The radioactivity content of these wastes should also vary depending on source of the ores. Ore in 1972 was produced in the U. S. in Florida, Georgia, New York, and New Jersey. Radioactivity associated with one processing plant is shown in Table 2.

In 1974, U. S. consumption of ilmenite, rutile, and titanium slag amounted to 588,000 short tons (contained titanium). Of this amount, 92 percent was used for pigment manufacture.[4] The remainder was used for manufacture of titanium sponge (metal), welding rod coatings, carbides, and in ceramic and glass formulations.

In 1979, six firms using 10 plants were producing titanium dioxide in the United States.

In 1980 there were three titanium metal producing plants operating in the United States. Two of these plants purchased $TiCl_4$ from a pigment plant while the third plant produced metal from rutile and leucoxene ore.

TABLE 1

Titanium Ores

Ore	Composition
Rutile	TiO_2
Ilmenite	$FeTiO_3$
Leucoxene	TiO_2
Anatase	TiO_2
Perovskite	$CaTiO_3$
Sphene	$CaTiSiO_5$

TABLE 2

TITANIUM-CHLORINATION PROCESS
AUSTRALIAN ORE

RADIONUCLIDE CONCENTRATION (pCi/g) [5]

MATERIAL	^{234}U	^{235}U	^{238}U	^{230}Th	^{232}Th	^{228}Th	^{226}Ra	^{210}Pb	^{210}Po
RUTILE	14.0 ± 1.4	0.68 ± 0.24	14.0 ± 1.4	17.0 ± 6.0	1.2 ± 0.4	2.0 ± 0.9	15.0 ± 2.0	8.5 ± 1.2	7.2 ± 2.6
LEUCOXENE	11.0 ± 1.4	0.59 ± 0.27	12.0 ± 1.6	10.0 ± 2.9	10.0 ± 3.3	11.0 ± 5.2	12.0 ± 1.9	12.0 ± 1.1	11.0 ± 2.1
CHLORINATOR BOTTOM DUMP	9.0 ± 0.6	0.34 ± 0.06	8.3 ± 0.6	15.0 ± 0.7	11.0 ± 0.6	11.0 ± 0.6	4.2 ± 0.9	3.3 ± 0.6	< 0.5
SLUDGE POND	27.0 ± 1.8	0.87 ± 0.10	26.0 ± 1.8	36.0 ± 5.3	7.6 ± 1.6	7.5 ± 1.5	17.0 ± 3.5	30.0 ± 2.2	30.0 ± 1.1
OLD SLUDGE	58.0 ± 3.5	1.6 ± 0.14	57.0 ± 3.6	77.0 ± 9.2	4.5 ± 0.9	4.6 ± 1.0	25.0 ± 5.3	39.0 ± 2.8	36.0 ± 2.1
TITANIUM SPONGE	0.69 ± 0.19	< 0.1	0.44 ± 0.13	0.35 ± 0.21	< 0.3	< 0.4	< 0.2	< 1.6	< 0.8

LIQUID WASTE STREAMS (pCi/l)

MATERIAL	^{234}U	^{235}U	^{238}U	^{230}Th	^{232}Th	^{228}Th	^{226}Ra	^{210}Pb	^{210}Po
ALPHA DITCH	3.1 ± 0.6	< 0.2	1.8 ± 0.5	2.0 ± 1.0	< 2.0	< 2.0	1.2 ± 0.2	< 6.6	< 3.6
PARSHALL FLUME	3700 ± 600	< 74.0	3300 ± 600	3300 ± 700	1200 ± 300	1600 ± 400	3900 ± 1200	1200	1400 ± 100
PROCESS WASTE TO LEACH LIQUOR POND	13.0 ± 2.0	< 0.59	12.0 ± 2.0	14.0 ± 5.0	5.4 ± 2.6	7.9 ± 3.4	7.5 ± 2.2	30.0 ± 10.0	26.0 ± 4.0
CAUSTIC POND	6.9 ± 2.2	< 0.63	5.7 ± 2.0	3.8 ± 3.3	< 2.9	< 2.9	4.8 ± 1.4	Lost	5.2 ± 3.8

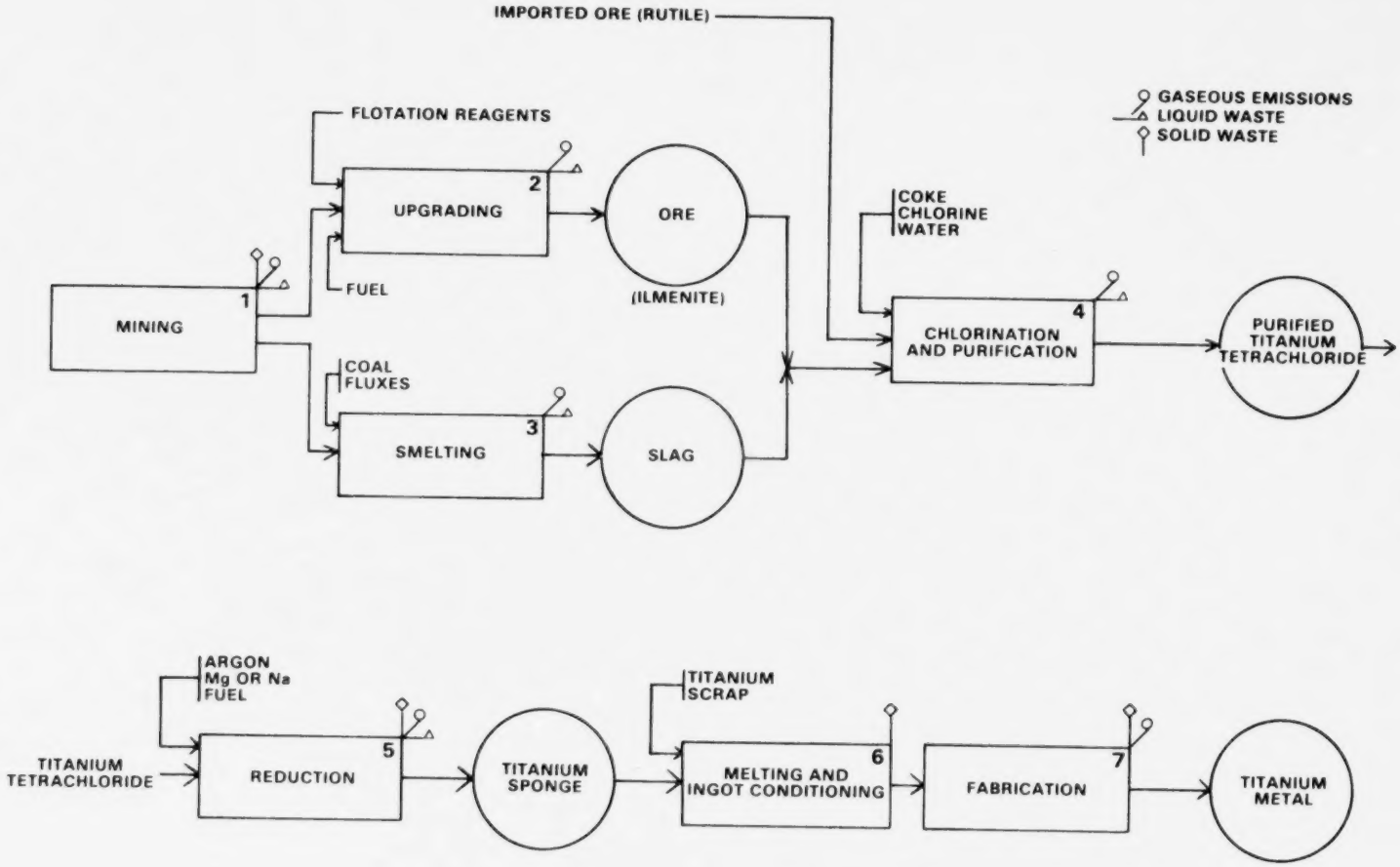


Figure 1. Titanium metal production[1]

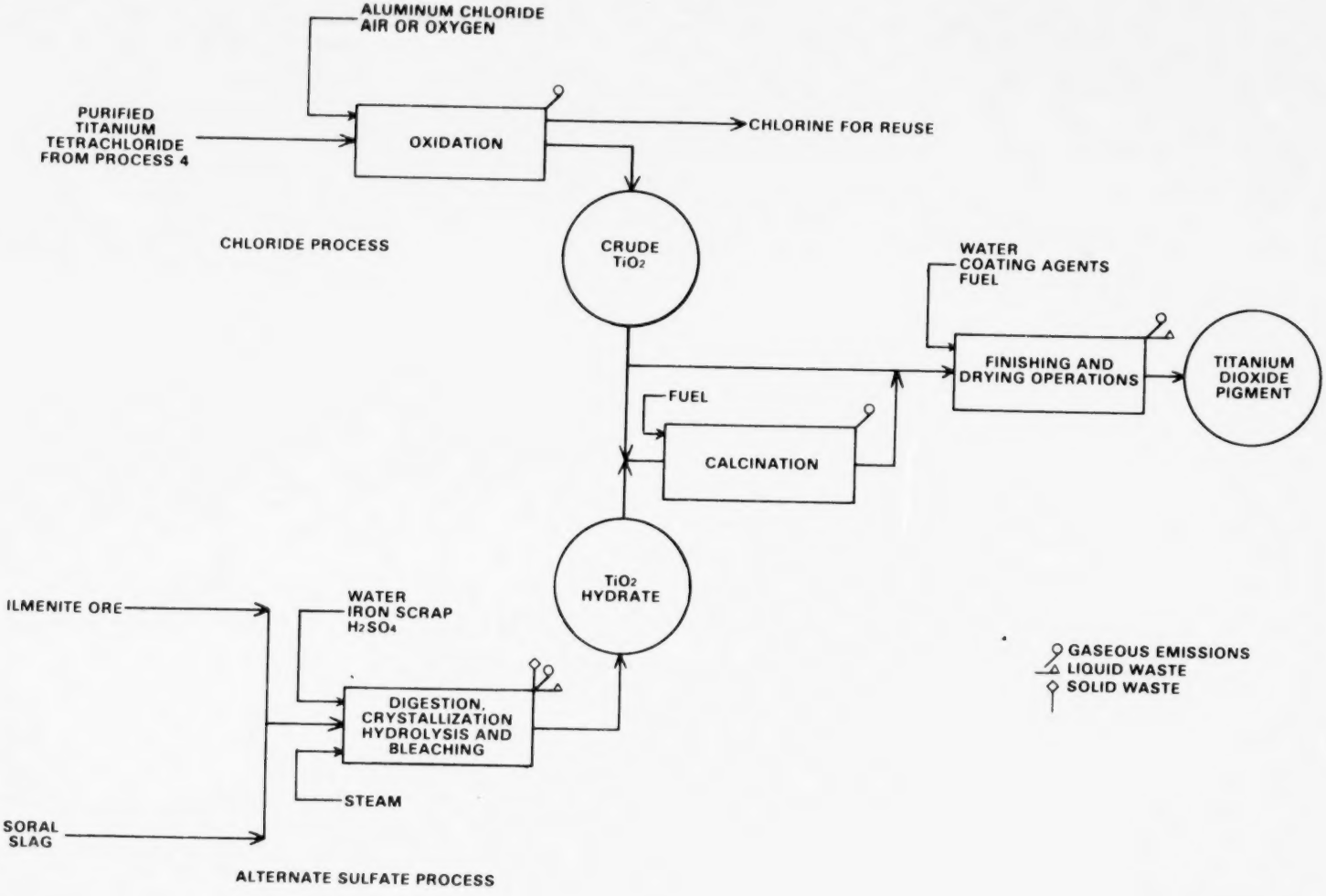


Figure 2. Titanium dioxide production[1]

References

1. Industrial Process Profiles for Environmental Use: Chapter 26. Titanium Industry. EPA-600/2-77-023Z. February 1977. Vishno S. Katari and Timothy W. Devitt. Industrial Environmental Research Laboratory. ORD/USEPA Cincinnati, Ohio 45268.

2. Industrial Minerals and Rocks (Nonmetallics other than Fuels). Stanley J. Leford, Editor-in-Chief. 1975. American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc. New York, N.Y.

3. Titanium - Its Occurrence, Chemistry, and Technology. September 1966. Jelks Barksdale. The Ronald Press Company. New York, N.Y.

4. Minerals Facts and Problems - Bicentennial Edition. Bureau of Mines Bulletin 667. 1975 Edition. U. S. Bureau of Mines. U. S. Department of Interior.

5. Donald W. Hendricks, Director, ORP Las Vegas Facility, USEPA, Las Vegas, NV. Private Communication.

TIN SMELTING

The only operating tin smelter on the North American continent is the plant in Texas City, Texas, belonging to Gulf Chemical and Metallurgical Company. The company imports tin ores from South America and smelts the ores to recover the tin. The company in earlier days poured the slag from the smelting into water. The thermal stress resulting from the contact of the molten slag with the water fractured the slag into sand-size shards. Great quantities of steam and smoke were liberated by this process. Recent air quality regulations have since led the company to pour the slag onto a dry area and break up the slag using machinery. Next, the slag is transported to the disposal area adjacent to the smelter.

Radiation surveys using 1" x 1" NaI scintillation instruments have found uncorrected radiation levels in this area ranging from 10 μR/hr to 500 μR/hr at various parts of the area, with readings higher than 60 μR/hr being uncommon. The highest radiation levels were associated with the older sand-like slag. Samples of slag from the most recent pour were obtained. One characteristic material of the major portion of the pour was a glassy, dense chunk, while the other material was a friable, frothy, highly vesicular and light material.

Laboratory analyses of the radioactivity in these samples are shown in Table 1.

Tin has not been completely removed from the slag, and the company has expressed an intention to re-smelt some of the slag for secondary tin recovery.

TABLE 1

Radioactivity Content of Tin Smelter Slag

	Dense Sample (pCi/g)		Friable Sample (pCi/g)	
Total Alpha (3 measurements)	235	175	90	90
Total Beta (3 measurements)	317	58	122	40
Gamma Radionuclide Analysis:				
Ra-226	28	5	6	1
Pb-214	38	1	9.0	0.4
Bi-214	42.7	1.5	10.9	0.3
Ac-228	7.5	1.0	0.8	0.2
Bi-212	11	3	1.4	0.7
Tl-208	19	2	5	1
K-40	3.4	1.5	0.7	0.3

Errors expressed represent 2 σ counting errors based on a single sample survey.

USE OF VOLCANIC PUMICE AND SCORIA

Pumice is a widely used aggregate in the manufacture of lightweight concrete. It is natural silicic glass produced as a molten froth by volcanism.[1] As the froth cools tiny gas bubbles are trapped which cause the material to remain extremely porous and minutely vesicular in structure. Its porosity makes the pumice very light in weight while the dead-air cells give it excellent insulating properties. One cubic yard of pumice pebbles weighs between 825 and 900 pounds compared to 2600 pounds for ordinary sand and gravel. Pumice is white to light gray or light tan in color.[2]

Scoria is another lightweight volcanic aggregate which is slightly heavier (1000-1500 pounds per cubic yard) than pumice. It is generally stronger than pumice and ranges in color from red or brown to black.[2]

Both pumice and scoria have been widely used for many years for production of hollow masonry blocks. Pumice was used over 2000 years ago in the construction of the great dome of the Pantheon in Rome. As a concrete aggregate it has been used in Germany since 1850 and more recently in many other countries such as Japan and New Zealand.[3]

In 1945 about a dozen plants in the Albuquerque area alone were turning out 30,000 or more blocks per day. The proportions of pumice or scoria to sand and cement have varied widely from manufacturer to manufacturer but generally the blocks are 40 to 50 percent lighter than a sand-concrete block.

Pumice aggregate has been shipped widely from New Mexico to other states since at least 1930. Pumice aggregate has been shipped for use in Colorado, Texas, Oklahoma, Kansas, Arizona, Nebraska, Missouri, Iowa, and Mexico, at least. One California plant had been in operation in 1947 for 18 years and was producing 45,000

pumice-concrete blocks per day in 1947. It has also been used for production of monolithic pumice concrete, prefabricated reinforced lightweight concrete panels, shingles and roof tiles, abrasives, acoustic panels, acoustic plaster, stucco, interior plaster, and masonry mortar. Pumice has been used as a soil conditioner for adobe soils, as a mulch for lawns and fruit trees, for hydroponic culture and as a carrying agent for insecticides and fertilizer. In 1946 the shipment of New Mexico pumice aggregate totaled about 75,000 cubic yards.[3]

World consumption of pumiceous materials in 1974 totaled 14.4 million tons with a U.S. consumption of 4.2 million tons. U.S. production in 1974 was slightly over 3.9 million tons. U.S. construction uses in 1974 totaled 3.9 million tons with principal uses being road surfacing, maintenance, ice control, concrete admixtures and aggregate, and railroad ballast. Other uses totaled 290,000 tons with 25,000 tons used for abrasive purposes.[5]

Because pumice and scoria deposits are widely scattered in volcanic areas, the chemical and radionuclide composition of samples from individual areas can be expected to vary widely. In 1976 and 1977 a preliminary study was conducted by State of New Mexico Environmental Improvement Agency and U.S. EPA Office of Radiation Programs staff to evaluate potential radiation exposures associated with the use of pumice concrete block in the Espanola/Santa Fe, New Mexico, area. The source of the pumice was two commercial pits near Santa Fe.

Radium-226 content of two pumice samples was 6.1 ± 0.45 and 5.6 ± 0.43 pCi/g respectively. An adobe slump block using 40% pumice aggregate was found to contain 2.2 ± 0.28 pCi/g radium-226 while a pumice block sample containing 65% pumice had a radium-226 content of 3.4 ± 0.34 pCi/g.

Although measurements of indoor radon progeny were made in selected structures in Santa Fe/Espanola, Shiprock, and Farmington, New Mexico, results were

inconclusive. There was some indication that the use of pumice block may increase the working level in the structure but working level measurements in general were too few and/or too erratically spaced over time to give reliable annual average working level values.

Average net gamma ray exposure rates measured in pumice structures ranged from 0.5 μR/hr up to 3.4 μR/hr as measured with pressurized ion chambers. The limited data indicates that the gross working level in structures containing pumice block may approach a value of 0.01 WL when the net indoor gamma exposure rate is approximately 3 μR/hr.[4]

References

1. Benjovsky, T.D. and D. M. Clippinger. Natural Light-Weight Building-Block Materials of New Mexico. Circular No. 10. New Mexico School of Mines and Mineral Resources. Socorro, New Mexico. October, 1945.

2. Clippinger, D. M. Building Blocks from Natural Lightweight Materials of New Mexico. Bulletin 24. New Mexico School of Mines. Bureau of Mines and Mineral Resources. Socorro, New Mexico. 1946.

3. Clippinger, D. M. and W. E. Gay. Pumice Aggregate in New Mexico -Its Uses and Potentialities. Bulletin 28. New Mexico School of Mines. Bureau of Mines and Mineral Resources. Socorro, New Mexico. 1947.

4. Douglas, R. L., Hans, J. M., Jr. and T. A. Wolff. Working Level Screening Survey of Structures Constructed of Materials Containing Pumice. Technical Note ORP/LV-78-6. Office of Radiation Programs-Las Vegas Facility, U. S. Environmental Protection Agency. Las Vegas, Nevada. May 1978.

5. Mineral Facts and Problems. 1975 Edition. Bureau of Mines. Bulletin 667. U.S. Department of Interior. 1976.

RADIOACTIVITY IN SELECTED MINERAL AND GEOTHERMAL SPRINGS AND WELLS

Development of geothermal resources is being increasingly pursued as an alternate energy source. Fluids from geothermal reservoirs can be enriched in trace mineral constituents and in naturally occurring radionuclides. Mineral springs whose waters contain enough dissolved minerals or gases to give it a taste can also be elevated in radioactivity. Mineral springs may also be thermal springs. Because of the interest in use of geothermal reservoirs several studies have been performed during the last few years to evaluate radioactivity levels in geothermal fluids.

A report by O'Connell and Kaufmann[1] gives radioactivity data from about 140 selected geothermal springs and wells located in Arizona, California, Colorado, Idaho, Nevada, New Mexico, Oregon, and Utah. Radionuclides measured were radon-222, radium-226, uranium-234, thorium-230 and thorium-232. Data are summarized in Table 1. The report also references several other studies performed in the United States and abroad. In a second report[2], O'Connell has presented a model to calculate potential radon and radon progeny exposures associated with various uses of geothermal waters.

Felmlee and Cadigan[3] have reported radium and uranium data for 116 mineral springs in the states of Arizona, California, Colorado, Idaho, Nevada, New Mexico, Utah, and Wyoming. Results are summarized in Table 2.

These studies generally indicate a significant disequilibrium of radon with respect to radium and a lack of correlation between radium and uranium. Radium mobility relative to uranium is apparently favored by water with high specific conductance, high temperature, and low pH. With a few exceptions, the quantities of uranium and thorium in the springs are not significant (i.e., generally less than 5-10 pCi/l).

From a public health viewpoint, radium-226 is the isotope of most concern in use of these springs for drinking water. If the water is used for other purposes such as heating of residences, apartments, motels, greenhouses, or indoor swimming pools, then radon and radon progeny become the radionuclides of concern. O'Connell[3] has calculated exposures for several hypothetical uses of geothermal waters.

Additional data on radium and uranium in drinking water are being gathered on a national basis as drinking water supplies are analyzed as required by the Safe Drinking Water Act (Public Law 93-523). Other studies are also being conducted on either a regional or national basis to evaluate radon in drinking water supplies.

References

1. O'Connell, M. F. and R. F. Kaufmann. "Radioactivity Associated with Geothermal Waters in the Western United States." March 1976. U. S. Environmental Protection Agency. Technical Note ORP/LV-75-8A.

2. O'Connell, M. F. and G. A. Gilgon. "Radioactivity Associated with Geothermal Waters in the Western United States - A Modeling Effort to Calculate Working Levels of Radon-222 and its Progeny for Nonelectrical Applications." April 1978. U. S. Environmental Protection Agency. Technical Note ORP/LV 75-8B.

3. Felmlee, J. Karen and Robert A. Cadigan. "Radium and Uranium Data for Mineral Springs in Eight Western States." 1978. U. S. Geological Survey Open-File Report 78-561.

Table 1

RANGE OF RADIONUCLIDE CONCENTRATIONS* IN WESTERN U. S. GEOTHERMAL WATERS (pCi/ℓ)

	Rn-222	Ra-226	U-234	U-238	Th-230	Th-232
Arizona	140-6500	0.084-6.9	0.03-10.0	0.01-3.8	0.011-0.18	0.0062-0.28
California	13-14,000	0.041-1500	0.02-3.7	0.06-4.9	0.30-15	0.10-1.1
Colorado	72-2100	0.12-27	0.039-4.6	0.033-2.2	0.0069-0.12	0.0043-0.027
Idaho	260-390	0.048-8.2	0.018-0.73	0.013-0.10	0.006-0.97	0.0063-0.0087
Nevada	41-3200	0.050-140	0.017-190	0.012-170	0.0077-12	0.0049-21
New Mexico	120-9400	0.16-140	0.07-12	0.05-5.2	0.61-4.0	0.10-1.18
Oregon	55-260	0.061-0.38	0.015-0.13	0.0079-0.032	0.017-0.028	0.010- 0.022
Utah	160-2600	0.15-410	0.033-1.4	0.015-0.93	0.008-0.26	0.006-0.2

*Data summarized from reference 1.

Table 2

RANGE OF RADIUM AND URANIUM CONCENTRATIONS IN WESTERN U. S. MINERAL SPRINGS*

	Ra-226 (pCi/l)	Total U(μg/l)
Arizona	0.10 - 120	0.5 - 13
California	2.3 - 15	0.64 - 2.2
Colorado	0.08 - 260	0.01 - 95
Idaho	0.53 - 28	0.01 - 0.40
Nevada	0.1 - 110	0.01 - 14
New Mexico	0.29 - 230	0.04 - 15
Utah	0.09 - 220	0.01 - 4.7
Wyoming	0.34 - 61	0.03 - 2.8

*Data summarized from reference 3. Includes some data from reference 1. The specific activity for natural uranium is 0.677 pCi/μg U.

RADIUM AND RADON IN GROUND WATER

Description of the Problem

Although radium-226 and radon-222 and the short-lived daughters polonium-218, lead-214, bismuth-214 and polonium-214 all occur naturally, man's exposure to them is often technologically enhanced. Many parts of the country are underlain by aquifers which contain radium and radon and which are used for domestic and municipal water supplies. Radium and radon, together or separately, have been detected in wells drilled through granitic rock and in coastal plain sediments, for example, and may be expected to occur in other geologically similar regions. The concentrations often vary widely from well to well even when they are separated by short distances; such variations are dependent on rock type, degree of metamorphosis and fracturing, the amount of overburden, and so forth. Radon, because of its gaseous form and mobility, is often found in water in which little or no radium is dissolved.

Ingestion is the primary pathway by which radium in drinking water affects man, although as we will discuss later, water treatment may result in elevated concentrations of radium and elevated radiation levels at the treatment plant. Since radon is a gas, there are two possible pathways. Water containing radon may be ingested or the radon may separate from the water and be inhaled along with room air.

In the case of ingestion any daughters which may be present will be ingested also. The case of inhalation is more complicated. Only the radon is sufficiently volatile to partition from the water. Since radon and its daughters have such short half-lives, equilibrium will be reached within hours in air into which radon is introduced if no further changes are made. However, some of the daughters are formed in a highly charged state and may attach themselves to airborne particles or to solid surfaces; the exact distribution of the resulting mixture is not easy to predict.

Health effects due to radium ingestion have been studied ever since the fate of the radium dial painters became evident in the 1920's. Effects due to radon its daughters are not so well characterized because of their different half-lives, chemical and physical properties and biological affinities. Although the Environmental Protection Agency has set standards for radium in drinking water, no such standard for radon currently exists. A former standard of 2000 pCi/l radon plus daughters was withdrawn in 1959 and has not been replaced.

Activities to Date

Locating sources: For several years the EPA has contracted with various agencies to survey potable water supplies for compliance with radium established by the Safe Drinking Water Act. A similar organized search for radon has just begun[1], although the surveys that have been done have found radon in excess of 2,000 pCi/l in 20% to 75% of the wells surveyed. It is true that the presence of radon was suspected because of the underlying geology in most of these cases and so the incidence of radon detected to date is probably not representative of the country as a whole. In North Carolina,[2] 34% of the wells had concentrations greater than 2,000 pCi/l. In South Carolina,[1] 20% of the surveyed wells exceed 2,000 pCi/l. Only one well in New Jersey and none in Oklahoma[1] exceeded 2,000 pCi/l. Travis et al[3] report that out of 642 sites, 21% exceeded 2,000 pCi/l and 5% exceeded 10,000 pCi/l. A survey in Maine[4] found concentrations as high as 280,000 pCi/l.

Removal

Radium concentrations in potable water may be reduced by diluting the supply, by finding new sources, or by water treatment. When water containing elevated levels of radium is treated, some provision must be made to isolate and dispose of the radium-bearing filter media and to insure that water treatment plant personnel are not exposed to elevated radiation levels around the filters and ion exchange columns.

Disposal of radium may be difficult and certainly will be expensive if such wastes must be sent to commercial low-level waste burial sites. Radon may be removed by aeration or by decay. Aeration does not remove the non-volatile progeny but the total concentration decreases rapidly once the parent radon is removed. Surveys of municipal supplies have shown that most treated water has greatly reduced concentrations of radon.[4] The principal health risk is probably to users of small private supplies which introduce well water directly into homes with little or no treatment. Studies are underway to develop reliable and affordable devices to remove radon from small supplies.[5, 6]

Health Effects

EPA established the drinking water standard based on the estimate that exposure to water containing 5 pCi/l of radium-226 or radium-228 could result in 0.3 to 5 fatal cancers per year per million person exposed; any potable supply which exceeds 5 pCi/l of radium-226 must be treated. We may take this as an acceptable level of risk to the public.

To assess the health effect due to radon in drinking water one must estimate the dose to the stomach due to ingestion for comparison with the dose to the lungs from inhalation. Furthermore, the airborne concentrations caused by domestic water consumption must be compared to concentrations arising from the underlying soil or from the building materials. Suomela et al calculated that ingestion of water containing radon would result in 240 to 340 Rem per Ci of radon ingested. Therefore 10,000 pCi/l would result in weekly doses of 34 to 48 mRem or 3.4 to 4.8 mRad. Using the BEIR III best estimate of 0.59 stomach cancers per million person-rads per year one expects to find 1 to 2 excess cancers per 10 million persons exposed.

The same concentration of radon in domestic water would result in approximately 1 pCi/l of radon in the air.[8, 3] The concentrations of the daughters

increase rapidly.[9, 10] The resulting airborne dose depends very much on the exact concentration of the various daughters and the fraction of each daughter which is not attached to dust particles.[11] By converting concentrations to working levels one can assess the relative risk to inhabitants. For example, the Surgeon General guidelines for the Grand Junction cleanup call for no action below 0.01 WL, further assessment between 0.01 and 0.05 WL, and remedial action above 0.05 WL. EPA predicts a lifetime total of 20,000 excess lung cancer deaths per million people exposed to 0.02 WL.[12] Depending on the degree of disequilibrium, 1 pCi/l of radon gives rise to between .0007 and 0.01 WL.[9] Estimated health risks therefore range from 700 to 10,000 excess cancer deaths per million persons exposed.

Ground water is not the only source of radon indoors. Emanation from the soil and from building materials is also important. Studies in Florida[12] found airborne concentrations of radon and progeny greater than 0.03 WL in 20% of the building surveyed. Similar results may be expected elsewhere.

Summary

Further attempts should be made to determine dose conversion factors and risks estimates in residential environments. Epidemiological studies in Maine have not found cancer incidences at levels which are predicted by existing dose models. A new standard for radon in domestic water should be established. It appears that the old standard of 2,000 pCi/l may be too low. Care must be exercised in establishing the new standard to balance the cost against the probable reduction in working levels and in dose commitments. Too low a level may result in great economic dislocation, not only from the imposition of remedial measures but also in reduced real estate values, without significantly reducing the personnel exposure in the home. The standard should address both the ingestion dose and the working level which would exist in the dwelling with and without the water supply.

References

1. Environmental Radiation Data: Report 19-20; USEPA Office of Radiation Programs; April, 1980.

2. M. K. Sasser and J. E. Watson; Health Physics 34, 667-671 (1978).

3. C. C. Travis, A. P. Watson, L. M. McDowell-Boyer, S. J. Cotter, M. L. Randolph and D. E. Fields; "A Radiological Assessment of Radon-222 Released from Uranium Mills and Other Natural and Technologically Enhanced Sources"; NUREG/CR-0573; U. S. Nuclear Regulatory Commission, February, 1979.

4. C. T. Hess, S. A. Norton, W. F. Brutseart, R. E. Casparius, E. G. Coombs and A. L. Hess; "Radon-222 in Potable Water Supplies in Maine: The Geology, Hydrology, Physics and Health Effects"; Land and Water Resources Center, University of Maine at Orono; 1979.

5. W. W. Groune, F. B. Higgens, B. M. Smith, J. R. Mahaffey, Jr., "Natural Radioactivity in Ground Water Samples in Maine and New Hampshire", Project No. A-473, Georgia Institute of Technology, Atlanta, GA (Oct 60).

6. K. L. Rost, Private Communications, Maine Department of Human Services, 1980.

7. M. Suomela and H. Kahlos; Health Physics 23, 641-652 (1972).

8. "Radiological Quality of the Environment in the United States, 1977"; EPA 520/1-77-009.

9. R. D. Evans; Health Physics 17, 229-252 (1969).

10. J. Porstendorfer, A. Wicke and A. Schraub; Health Physics 34, 465-473 (1978).

11. R. Colle', ed.; "Radon in Buildings"; National Bureau of Standards Publication 581; June, 1980.

12. R. J. Guimond, W. H. Ellett, J. E. Fitzgerald, S. T. Windham, and P. A. Cuny; "Indoor Radiation Exposure Due to Radium-226 in Florida Phosphate Lands"; EPA 520/4-78-013; February, 1978.

Soil Contamination Guidance
1980 Recommendation

I. Applicability

This guidance is provided in an effort to promote uniformity and conservatism in addressing man-made soil contamination situations where the general public has access. The guidance includes man-made radionuclides as well as NORM because of the 1979 expansion of the Committee's charge as discussed on page 2.

II. Guidance Values

A. Every effort must be made initially to reduce the contamination values to background levels for the locale involved.

B. In the event complete removal of the contamination to background levels is technically or economically impractical, contamination above background levels may remain at the location, provided the values from a representative sampling of the impacted area do not exceed 10% of the concentrations stated in the Conference of Radiation Control Program Directors, Inc., "Suggested State Regulations for Radiation Control," Part D, Appendix A, Table II, Column 2, for insoluble radionuclides in water* for alpha and beta/gamma emitting materials. (See Column A, page 75)

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*The values stated in the SSRRC are in microcuries per milliliter (μCi/ml) of water above natural background. These must be converted to picocuries per gram of soil (pCi/g) by substituting grams for milliliters directly, and by adjusting microcuries to picocuries by the appropriate factor (10^6).

C. In any event, should the levels exceed 100% for beta/gamma emitters and 20% for alpha emitters of the values specified in the Conference of Radiation Control Program Directors, Inc., "Suggested State Regulations for Radiation Control," Part D, Appendix A, Table II, Column 2 for insoluble radionuclides in water*, the soil contamination shall be controlled by the removal of the contamination or other appropriate means. (See Column B, Page 75).

D. Where combinations of radionuclides are involved, the sum of the ratios between the concentrations present and the guidance value for the individual radionuclide shall not exceed 1.

III. Procedures

A. Soil sampling must be representative of the area impacted and the potential hazard. Samples taken should be from a one (1) centimeter depth. The area over which samples are taken should be measured. Soil depth profiles may be necessary in certain cases. The aliquot analyzed for contamination should be homogeneous and have soil particles of less than two (2) millimeters in size. Size separation should be done by simple mechanical means. Analytical procedures

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*The values stated in the SSRRC are in microcuries per milliliter (μCi/ml) of water above natural background. These must be converted to picocuries per gram of soil (pCi/g) by substituting grams for milliliters directly, and by adjusting microcuries to picocuries by the appropriate factor (10^6).

should follow the techniques recommended by the HASL-300 document or similar publications, and the results traceable to the standards of the U.S. National Bureau of Standards. Quality assurance, including cross-check measurements, should be an integral part of the sampling and analysis program.

B. In all cases, fully document all actions, procedures and decisions made for future reference and re-evaluation.

IV. Other Guidances and Standards

This guidance is provided at this time in the absence of other guidances and standards generally applicable to soil contamination situations. Upon the provision of federal guidances and standards on such matters, they may take precedence over the recommendations provided herein, as appropriate.

V. Disclaimer

This guidance is provided to assist regulatory authorities in evaluating soil contamination situations. Due to technical and legal complexities of soil contamination scenarios, this guidance cannot be generally applied in all situations and each case must be evaluated on its own merits.

TABLE 1

SOIL CONTAMINATION GUIDANCE FOR SELECTED RADIONUCLIDES

Isotope	Column A Concentrations Below Which Removal or Controls are not Mandatory[1] (pCi/g)[2]	Column B Concentrations Above Which Removal or Controls are Mandatory[3] (pCi/g)[2]
Americium-241	3	6
Antimony-125	10	100
Bismuth-207	6	60
Cadmium-109	20	200
Carbon-14	80	800
Cesium-137	4	40
Cobalt-60	30	300
Europium-152	8	80
Europium-154	2	20
Europium-155	20	200
Hydrogen-3	300	3000
Iodine-129	20	200
Iodine-131	6	60
Iron-55	200	2000
Nickel-63	70	700
Plutonium-238	3	6
Plutonium-239	3	6
Plutonium-240	3	6
Promethium-147	20	200
Radium-226	3	6
Radium-228	3	6
Sodium-22	3	30
Strontium-90	4	40
Technetium-99	20	200
Thallium-204	6	60
Thorium-230	3	6
Thorium-232	4	8
Uranium-234	3	6
Uranium-238	4	8

NOTES:

1. It must be emphasized that every effort must be made to reduce contamination to background levels and that the limits in this table only apply when it is technically or economically impractical to do so. Column A values were derived as described in II.B above.

2. Dry weight.

3. Levels of contamination between Column A and Column B require evaluations on a case-by-case basis as to whether or not removal or controls are needed. Column B values were derived as described in II.C above.

The following table, while in no way is intended to be conclusive or all encompassing, represents information submitted by individual states in response to a request from the Task Force. The Conference sincerely appreciates the efforts of responding states and anticipates completion of a comprehensive inventory in the near future.

NORM INVENTORY

Industry	Source/Activity	Location(s)	Radioactive Product or By-Product	Isotopic Concentration
Construction	Phosphate Slag	Alabama	Concrete Block	Ra-226 10 pCi/gm
Uranium Mine & Mill	Ore	Arizona	Uranium Oxide U_3O_8	Uranium series
Copper Mines	Leaching Cu ore for Uranium	"	Tailings piles	U & Th series
Insulation (Building)		California	Rock wool Fiberglass wool	Ra-226 6.6 pCi/g Ra-226 0.5 pCi/g
Uranium Mines & Mills	Ore	Colorado	Uranium Oxide U_3O_8	Uranium series
Fluorospar Mine & Mill	Ore	"	Tailings piles	Uranium series
Molybdenum Mine	Ore	"	Tailings piles	Uranium series
Water wells		"	Contaminated wells	Ra-226 3-470 pCi/liter
Insulation (Building)		"	Spun mineral wool	Ra-226 5.5 pCi/g
Phosphate	Phosphate ore	Florida	Overburden	Ra-226 18-84 pCi/g
		"	Overburden spoils piles	Ra-226 2-7 pCi/g
		"	Pebble	Ra-226 44-97 pCi/g
		"	Slimes	Ra-226 34-58 pCi/g
		"	Concentrate	Ra-226 26-50 pCi/g
Heavy minerals		"	Sand tailings	Ra-226 2-12 pCi/g
		"	Fuller's earth	Ra-226
		"	Zircon sand	U & Th series up to 0.1% U & Th

Industry	Activity	Location(s)	Radioactive Product or By-Product	Isotopic Concentration
Mining	Ore	Georgia	tailings piles	Uranium series
Phosphate	Mining	Idaho	Ore/slag	Ra-226 26-32 pCi/g
Phosphate		Illinois	Fertilizer	Ra-226 13 pCi/g
Potash		"	Potash	Thorium series
Foundry	Metal casting	"	Casting molds	Thorium series
Aluminum	Alloy casting	"	Casting molds	Th-232 0.0016-0.0033 μCi/g Ra-226 0.0009-0.0012 μCi/g
Waste Treatment	Water purification	Iowa	Treatment sludge Ion charge waste water	Elevated Radium
Coal mining	Mining	Indiana	Mine tailings	
Coal plants	Electric power	"	Fly & bottom ash	
Foundry	Metal casting	"	Casting molds	Thorium series
Phosphate	Mining	Montana	Ore/slag	Ra-226 38-40 pCi/g/20-48 pCi/g
Uranium mine	Mining	New Mexico	Mine tailings	Uranium series
Uranium mill	Milling		Mill tailings	Uranium series
Coal plants	Electric power	New York	Fly & bottom ash	U & Th series
Coal mine	Mining	Oklahoma	Mine tailings	U & Th series
Coal plants	Electric power	"	Fly & bottom ash	U & Th series, Ra-226
Steel	Tantalite/Columbite ores	"	Slag	U & Th series
Ra Spa	Healing Arts	"		Ra-226 Rn-222

Industry	Activity	Location(s)	Radioactive Product or By-Product	Isotopic Concentration
Phosphate	Phosphoric acid production	Louisiana	Phospho-gypsum	Ra-226 20-30 pCi/g
			Phosphoric acid	U-238 100,000 pCi/l
Aluminum	Production of alumina	"	Bauxite tailings	Ra-226 20-30 pCi/g
Foundry	Casting Molds	Oregon	Waste molds	U & Th, Ra-226 100 pCi/g
	Glass bottles	"		Ac-228 133 pCi/g
Zirconium	Metal	"	Chlorinator residue	Ra-226 491 pCi/g
Phosphate	Phosphatic limestone	Tennessee	Slag, ferrophos	Uranium series
Extraction	Shale	"		Uranium series
Mining	Sands	"	Monazite	U & Th series
Foundries	Metal castings	"	Molds	Uranium series
Coal plants	Electric power	"	Fly & bottom ash	Uranium series
Mining	Ore	"	tailings piles	Uranium series
Titanium	Metals	"		U & Th series
Mining	Uranium ore	Wyoming	Mine tailings	Uranium series

RADIATION PATHWAYS FROM INCIDENTAL NORM USE OR DISPOSAL

Table 1 is a list of some of the known pathways from the use or disposal of materials containing incidental NORM. "Incidental," means that the radioactivity was not intentionally introduced into the material and that the material is not useful because of its radioactivity. Exposures from such radioactivity has been defined as "Technologically Enhanced Natural Radioactivity" (TENR)[1] exposures.

The Table includes the use of the material, the ultimate disposition and typical radiation or radioactivity levels associated with the material. There are many blanks in the Table due to a lack of information. As the footnotes indicate, in determining ultimate disposition, a maximum period of 1000 years was chosen, consistent with recommendations of the EPA.

The specific pathways from uranium mining and milling and the burning of coal were not listed, but are described in greater detail in other documents.

The Committee believes there is a definite need to evaluate the radiological aspects of each of the dose pathways listed in Table 1. Specifically, a determination of the population dose increments (person-rem/year) for each pathway is needed. If population dose increments for dose pathways are known, then determinations can be made regarding the relative radiation hazard involved, and decisions can be made regarding the need for restrictions or controls.

At least three Federal agencies, EPA, NRC, and BRH have the responsibility to evaluate the radiological aspects of the pathways. The DOE would also be involved in the evaluation of energy facilities. The Committee recommends that these agencies begin such evaluations as soon as possible.

TABLE 1

Radiation Pathways from Incidental[1] NORM Use

Radioactive Product or Byproduct	Storage/Use	Disposition[2]	Typical Radiation Or[6] Radioactivity Levels (Gross)
Phosphate Ore	Phosphate Mining Overburden	Dispersion into Populated and Unpopulated Areas	10 to 30 pCi/g Ra-226 on reclaimed land; maximum 0.1 WL in houses
	Mining Slimes	Mined Out Areas	10 to 2000 pCi/l suspended Ra-226
	Fertilizer Manufacture	Processed	20 to 40 pCi/g Ra-226
	Elemental Phosphorus Extraction	Processed	20 to 40 pCi/g Ra-226
	Steel Manufacture	Steel Slag Uses	5 μR/hr 2.9 pCi/g Ra-226
Phosphate Slag	City Street Construction Playgrounds, sidewalks, driveways, parking lots	Dispersion into Populated Areas	20 to 60 μR/hr 3 feet above street
	Highway Construction Farm Roads	Mostly Unpopulated Areas	20 to 60 μR/hr 3 feet above road
	Drain Fields	Dispersion into Populated Areas	35 pCi/g Ra-226 in slag
	Railroad Ballast	Railroad Lines	10 to 20 μR/hr 3 feet above tracks
	Roofing	Dispersion into Populated Areas	3 μR/hr at ceiling
	Home or Commercial Insulation	Dispersion into Populated Areas	13-16 pCi/g Ra-226
	Glass Making	Dispersion	
	Aggregate in Concrete for Homes and in Other Construction	Dispersion into Populated Areas	10 to 60 μR/hr in structure .01 WL in buildings or houses
	Slag Piles	Unknown or as above	90 to 150 μR/hr

Radioactive Product or Byproduct	Storage/Use	Disposition[2]	Typical Radiation Or[6] Radioactivity Levels (Gross
Phosphate Gypsum	Soil Conditioner	Agricultural Areas	20 pCi/g Ra-226
	Wallboard	Dispersion into Populated Areas	20 to 30 pCi/g Ra-226
	Foundation Base	Dispersion into Populated Areas	20 pCi/g Ra-226
	Drain Pipes	Dispersion into Populated Areas	
	Gypsum Piles	Unknown or as above	20 pCi/g Ra-226
Phosphate Livestock Feed Supplement	Livestock Feed	Food Chain	0.7 pCi/l Ra-226 in milk
Phosphate Fluid Bed Prills	Fertilizer	Agricultural Areas	1300 pCi/g Po-210
Phosphoric Acid[7]	Fertilizer and Commercial Poducts	Dispersion	50,000 to 100,000 pCi/l U-2
Phosphate Fertilizers	Agricultural	Dispersion	5 to 20 pCi/g Ra-226; 1000 pCi/l Ra-226
Tobacco	Cigarettes, Cigars, Other Tobacco Products	Consumed by Public	Average 0.44 pCi/g Po-210
Coal[3]	Fuel for Power Plants	Consumed in Power Plants	Few ppm up to 10% U
Natural Gas	Fuel for Cooking, Heating	Consumed or Decays in Storage	20 pCi/l Rn-222 average
Liquified Petroleum Gas	Fuel for Cooking and Heating	Consumed or Decays in Storage	1 - 1450 pCi/l Rn-222
Potable Water	Drinking Water	Consumed or Stored to Decay	Trace to greater than 100,000 pCi/l Rn-222; 750 pCi/l Ra-226
Treatment of Sludges and Resins	None	Dispersal	
Waste Water	None	Dispersal	
Cave Air	Breathing-Ventilation	Decay	.05 - .5 WL
Salt Brines incidental to Oil Production	Disposal Snow Melting	Reinjection and Dispersion to Swamps, Waterways, and Ocean	1 - 1800 pCi/l Ra-226

Radioactive Product Byproduct	Storage/Use	Disposition[2]	Typical Radiation Or[6] Radioactivity Levels (Gross)
Granite	Construction Materials	Dispersion into Populated Areas	46 μR/hr
Refractory sands or Clays	Firebrick	Dispersion into Populated Areas	35 μR/hr @ surface from one brick
Pumice	Construction Materials	Dispersion into Populated Areas	25 μR/hr
Brick	Construction Materials	Dispersion into Populated Areas	16 to 28 μR/hr
Concrete	Construction Materials	Dispersion into Populated Areas	12 to 130 μR/hr
Chemical Plaster	Construction Materials	Dispersion into Populated	50 to 70 μR/hr
Geothermal Water	Heating, Power Generation, Spas	Waterways	Ra-226 up to 1500 pCi/l Rn-222 up to 14,000 pCi/l
Volcanic Tuff	Construction Materials	Dispersion into Populated Areas	24 μR/hr
Ilmenite	For Iron Content in Portland Cement	Dispersion into Populated Areas	50 to 100 pCi/g Ra-226 in ilmenite - 1% by weight ilmenite in cement
Cerium Flour	Color Inhibitor in Glass Bottle Manufacture	Dispersion into Populated Areas	133 pCi/g Ac-228
Zircon Sand	Zirconium Extraction	Processed	100 pCi/g Ra-226
	Molds for Metal Casting	Landfills	10-150 pCi/g Ra-226
	Sandblasting	Dispersion	100 pCi/g Ra-226
	Weight in Tape Dispensers	Dispersion into Populated Areas	100 pCi/g Ra-226, 0.3 μR/hr @ 2 feet
	Sanitary Ware		
Zircon Extraction Chlorinator Residues	None	Radioactive Waste Disposal	100 to 1300 pCi/g Ra-226
Zircon Extraction Sludge	Soil Conditioner	Agriculture	90 μ/hr @ 3 feet

Radioactive Product or Byproduct	Storage/Use	Disposition[2]	Typical Radiation Or[6] Radioactivity Levels (Gross)
Zirconium Silicate	Dental Polishing Compound	Effluent from Dental Offices	62 pCi/g Ra-226
Duratherm	Metal Casting	Foundry Waste	108 pCi/g Ra-226
Rutile	Metal Casting	Foundry Waste	Not Available
Tin Ore	Tin Smelting	Processed	10 μR/hr
Tin Smelter Slag	Stored	Reprocessed	30 pCi/g Ra-226
Copper Ore	Copper Extraction	Processed	12 pCi/g Ra-226
Copper Mill Wastes	Road Construction Soil Conditioner	Dispersion into Populated Areas	0.6-66 pCi/g Ra-226
Manganese Slag			7.2 pCi/g Ra-226
Aluminum Ore (Bauxite)	Alumina Production	Processed	5 pCi/g Ra-226
Alumina Extraction Waste (red mud slurry)	Impounded	Unknown	20-30 pCi/g Ra-226
Titanium ores (Rutile Ilmenite, Leucoxene, etc.)	Titanium Extraction Pigment Manufacture	Processed Waste to Landfill	Rutile - 15 pCi/g Ra-226 Leucoxene - 12 pCi/g Ra-226
Uranium Ores[4]	Uranium Extraction	Processed	Gamma, radon progeny exposures
Sodium Uranyl Carbonate	Glass (Fluorescent and Iridescent)	Dispersion into Populated Areas	10% Uranium maximum
Sodium Uranite	Glazed Tableware, Pottery	Dispersion into Populated Areas	20% Uranium maximum
Uranium Oxides	Glazed Tableware, Pottery	Dispersion into Populated Areas	20% Uranium Maximum
Uranium Salts and Depleted Uranium	False Teeth and Crowns (Porcelain)	Burial	60 rem/yr to basal mucosa of mouth (alpha)
Uranium (depleted)	Radiation Shields	Licensed Disposal Site	360,000 pCi/g U-238
Uranium (depleted)	Weights in Aircraft	Licensed Disposal Site	360,000 pCi/g U-238

Radioactive Product or Byproduct	Storage/Use	Disposition[2]	Typical Radiation Or[6] Radioactivity Levels (Gross)
Thorium and Thoria	Gas Lamp Mantles	Dispersion - Trash - Landfill	30 μR/hr surface
	Metal Casting	Foundry Effluents	90,000 pCi/g Th-232
	X-ray Tube Targets		
	Ordinary Light Bulb Filament	Trash - Landfill	5,000 pCi/bulb maximum
	Sunlamps, Germicidal Lamps, Outdoor Lamps	Trash - Landfill	0.22 μCi/bulb
	Welding Rods		10% Th-Mo
	Magnesium Alloy for Aircraft and Other Industrial Parts	Dispersion	> 4% Th maximum
	Salvage Magnesium Alloy	Dispersion	4% Th maximum
	Ceramics for crucibles, refractories	Dispersion	
	Optical Glass	Dispersion	0.05 to 30% Th
	Catalyst in Sulfuric Acid Production		
	Catalyst in Nitric Acid Production		
	Catalyst in Water Gas Production		
	Catalyst in Petroleum Cracking		
	Photographic Film, Negatives, Prints		
	Nickel Alloy in Aircraft Parts	Dispersion	4% Th maximum
	Ceramics for Electronic Components	Dispersion	
	Ceramics for Glazed Tableware	Dispersion	

Radioactive Product or Byproduct	Storage/Use	Disposition[2]	Typical Radiation Or[6] Radioactivity Levels (Gross)
Thorium and Thoria (continued)	Ceramics for Brick, Tile, Other Construction Materials	Dispersion into Populated Areas	
	Nickel Alloy Thorium Heliarc	Magnesium Alloy Production	40% Th maximum
Monazite[5]	Thorium Extraction	Processed	80,000 pCi/g Th-232 in monazite
Other Thorium Ores[5]	Thorium Extraction	Processed	Gamma and thoron progeny exposures

Radioactive Product or Byproduct	Storage/Use	Disposition[2]	Typical Radiation Or[6] Radioactivity Levels (Gross)
Thorium and Thoria (continued)	Ceramics for Brick, Tile, Other Construction Materials	Dispersion into Populated Areas	
	Nickel Alloy Thorium Heliarc	Magnesium Alloy Production	40% Th maximum
Monazite[5]	Thorium Extraction	Processed	80,000 pCi/g Th-232 in monazite
Other Thorium Ores[5]	Thorium Extraction	Processed	Gamma and thoron progeny exposures

FOOTNOTES

(1) The table does not include pathways from the intentional introduction or use of radiation from NORM. Consequently, exposures from luminous dials, smoke detectors, etc., are not included. Exposures from radium contaminated gold or platinum are also excluded.

(2) In designating ultimate disposition, a maximum time period of 1000 years was considered.

(3) Pathways such as the use of coal fly ash, leaching from fly ash piles, etc., are being studied by the U. S. EPA, and some information is already available in EPA reports.

(4) The pathways from uranium mining and milling are described in detail in various reports of the U. S. EPA, NRC , and other agencies.

(5) The pathways from thorium mining and milling are described in detail in various reports of the U. S. EPA and other agencies.

(6) Where concentration of single isotopes are given, parents or progeny may also be present.

(7) Refers to acid which has not undergone uranium recovery.

REFERENCE

(1) Gessell, T. F. and Pritchard, N. M., The Technologically Enhanced Natural Radiation Environment. Health Physics, V. 28, No. 4, 1975

SUGGESTED STATE REGULATIONS FOR PROTECTING THE PUBLIC HEALTH AND SAFETY FROM NORM USE AND DISPOSAL

The Radiation Pathways listed in the preceding chapter of this report demonstrate that there is a need to answer many questions regarding the use and distribution of NORM in our environment. Some of the more significant questions that must be answered are as follows:

(1) Should phosphate slag be used for street and road construction or for other purposes?

(2) Should phosphate gypsum be used as a soil conditioner, and, if so, would any restrictions on such use be appropriate?

(3) Should the production or distribution practices of radioactive fertilizers be prohibited, modified, or limited in any way?

(4) Should phosphate plants and foundries be licensed, and what restrictions should be imposed on disposal of solid wastes containing NORM generated by these industries?

(5) Should zirconium extraction sludge be distributed on agricultural land as a soil additive?

(6) Should monazite or zircon sand be used and distributed in commercial products such as tape dispensers?

(7) Should fly ash be used in construction materials?

(8) In those areas of the U.S. where ground water contains significant quantities of radium-226, how should water treatment wastes (sludge and backwash water) be disposed of? Should these sludges be used as a soil sweetner?

(9) How should pollution abatement wastes from coal-fired electrical generating facilities be disposed of?

(10) To what extent should radon in potable water be controlled?

There may be other even more significant questions regarding these dose pathways but at the present time not enough is known about these pathways or radiation levels to ask the pertinent questions.

One approach would be to define a de minimus level or concentration of NORM for all products or by-products below which no regulatory controls would be required or various de minimus levels of NORM could be defined for each product or by-product depending on its use. The Committee has determined that this approach is not feasible for NORM for two reasons. First, NORM is ubiquitous; therefore any derived limit would eliminate or restrict the use of some materials regardless of the benefit or risk involved. Secondly, the use of de minimus levels is not consistent with current ALARA philosophy in that the application of ALARA implies the use of risk-benefit analysis rather than fixed numerical values. In other words, use of de minimus levels in the case of NORM could result in undue risk. Futhermore, use of a de minimus level would not preclude the necessity of risk-benefit analysis to determine appropriate regulatory controls. Nevertheless, the Committee partially defined a de minimus level in definition (a) below.

The answers to such questions as those on the preceding page would reasonably depend on the population dose increments (person-rem) involved, the risks from the population dose increments (ill-health effects), the benefits of accepting the risks (monetary and other factors), and the cost of eliminating or lowering the risks (monetary and other factors). However, even if all the above factors were perfectly known, there would still be a need for the criteria of acceptability. In other words, an "undue radiation risk from NORM" must be defined.

The Committee recommends that the Suggested State Regulations and all state regulations consider a definition of "undue radiation risk to the public health

and safety from NORM use or disposal." The Committee suggests the following definition:

"Undue Radiation Risk to the Public Health and Safety from NORM Use or Disposal" means:

(a) Exposure of any individual in the population to concentrations of naturally occurring radioactive materials in excess of those concentrations listed in Part D, Table II, Schedule A, of the Suggested State Regulations or;

(b) Exposure or reasonable potential exposure of any individual in the population to radiation in excess of background without a demonstrated benefit which outweighs the risk as determined below.

Risk-benefit analyses may be performed using the following criteria:

(a) Health care costs due to population dose increments (person-rem) to the whole body, bone marrow, or gonads should not exceed the monetary benefits of the NORM[1] use.

(b) Health care costs due to population dose increments (person-rem) to the lungs (or doses to parts of the lungs distributed over the entire masses of the organs) should not exceed the monetary benefits of the use or disposal mode of NORM[1].

(c) Health care costs due to population dose increments to any part of the skin (person-rem) should not exceed the monetary benefits of the use or disposal mode of NORM[1].

Examples of the above are given in Attachment C along with additional considerations which could be used in performing the analysis.

It is the intent of this regulation to insure that none of the above criteria be exceeded through any use or disposal of NORM.

As of this date, the Suggested State Regulations and all state regulations prohibit the use of radioactive materials unless authorized by a license or unless exempted. (Sec. C.1(a) of the Suggested State Regulations). The exemptions listed generally include only man-made radioactive materials and not NORM (Sec. C.4(a) and (b) of the Suggested State Regulations). Therefore, according to the Suggested State Regulations and most state regulations, all NORM should be licensed, regardless of concentration or quantity. It is true that there are specific exemptions for source material and certain items (Sec. C.3 and C.4(c) of the Suggested State Regulations), but these exemptions are not inclusive enough. The Committee recommends that the Suggested State Regulations and all state regulations be amended to include an exemption for NORM licensing (or controls) as follows:

Sec. C.4 Radioactive Material Other than Source Material

(g) Exempt Quantities or Concentrations of NORM

Any person is exempt from this part to the extent that such person uses or disposes of quantities or concentrations of NORM contained in industrial products, industrial byproducts or commercial products, provided that the use or disposal of such quantities or concentrations or NORM does not result in an undue radiation risk to the public health and safety, as defined in Part A of these regulations.

It is necessary, upon adoption of the above exemption, to remove radium from Schedule A, Part C, of the Suggested State Regulations and individual state regulations. The present values of 0.1 pCi/g for radium-226 and 0.3 pCi/g for radium-228 in Schedule A in many state regulations are not reasonable, since many common rocks and other materials contain concentrations above these values. The latest revision (10/78) of the SSRCR reflects this deletion.

It is also necessary, upon the adoption of the above regulation (Sec. C.4(g)), to define undue radiation risk, and the definition suggested in this report is recommended.

In Report No. 1 of this Committee (Natural Radioactivity Contamination Problems), it was recommended that states adopt a new regulation pertaining to Radiation Safety Requirements for Radioactive Mineral Tailings and Industrial By-product Piles. It is suggested that this regulation pertain to any pile of material which could present an "undue risk" either through use of the site containing the pile or through the indiscriminate use of the tailings or material. Present criteria for applicability of the regulation is a concentration of radioactive material in excess of 0.1 pCi/g.

An alternative to the above is to define concentration of NORM below which regulatory control is not necessary using the previous definition of undue risk.

[1]FOOTNOTE: As of 1979, health care costs can be based on the following cost criteria:

(a) $1000 per person-rem (whole body, bone marrow or gonad)

(b) $250 per person-rem (lungs)

(c) $15 per person-rem (skin)

Doses limited to other parts of the anatomy from NORM may be assumed to be equivalent to lung doses.

RECOMMENDATIONS

The following recommendations are both additions, combinations and revisions to the nineteen recommendations from the earlier report. They are not intended to totally replace those earlier recommendations which applies in Attachment E.

1. The Committee feels that it is primarily the responsibility of the EPA, NRC, FDA and DOE to evaluate the radiological pathways contained within this Report and recommends that these agencies begin such evaluations as soon as possible.

2. The Committee recommends that the Suggested State Regulations for Radiation Control and all state regulations be amended to provide for NORM licensing (or control) as described in this Report.

3. A new standard for radon in drinking water should be established after re-evaluating the dose conversion factors, risk estimates, and the apparent lack of health effects in the residential environment found to date. Both the ingestion and inhalation dose should be addressed coupled with a data base for use in setting the standard.

4. Slag from thermal process phosphorus acid plants should not be used for any purpose that results in its being under or within an enclosed structure. Any other use of slag should be thoroughly evaluated.

5. States, where applicable, should adopt regulations pertaining to control of radioactive mineral tailings and industrial byproduct piles. States should investigate their statutory authority over naturally-occurring radioactive material and if necessary, enact appropriate legislation.

6. It is recommended that the use of phosphate by-product materials, particularly gypsum, for agricultural uses not be discouraged at this time. Additional controlled studies should be performed to document the anticipated minimal environmental impact of this use.

7. States should continue to inventory mineral mining and processing operations and examine potential radiological aspects of their effluent, emissions, products and wastes. A report of the inventory and other findings should be submitted to the Committee with any pertinent recommendations where available.

8. In view of the measured high concentration of radium-226 in oil brines, the impact of uncontrolled discharge of these brines on the biosphere should be evaluated by appropriate State and Federal agencies.

9. EPA should study the uptake of naturally-occurring radionuclides in food crops from irrigation water, fertilizer, and soil.

10. This Committee recommends that a thorough evaluation be undertaken concerning the occurrence of radon-222 as a source of possible radiation exposure in State and privately-owned caves.

11. EPA should develop national criteria and guidelines concerning the use and distribution of industrial byproducts containing naturally-occurring radioactive material. The EPA should consider seeking appropriate authority to promulgate such guidelines as national standards.

12. EPA and appropriate States should study and evaluate all uses of fly-ash from coal-fired plants, particularly related to construction materials.

13. The radiological aspects of each proposed coal-fired plant should be evaluated by the appropriate agencies. Radioactive releases should be estimated from an analysis of the coal to be consumed and the operating characteristics of the proposed plant. This recommendation is especially pertinent to any proposed plant that intends to derive its fuel from low-grade, uraniferous Western coals.

14. The Committee recommends that States follow the guidance listed in the Chapter when licensing facilities for the recovery of uranium from wet process phosphoric acid plants.

15. Water plant filters which concentrate radium should be evaluated to assure proper disposal. Radiation levels around plant equipment should be measured.

ATTACHMENT A

RADIATION SURVEY OF A MINERAL DISPLAY

The Oregon Radiation Control Section has performed a radiation survey on all samples contained in the Oregon Department of Geology mineral display in Portland, Oregon. The survey was conducted in October 1978 with a Ludlum micro-R meter which was calibrated with an NBS radium-226 source.

This mineral collection is quite small (about 220 separate minerals), and it is, of course, not a representative sample of the earth's materials. Also, radioactivity in small samples of minerals containing on the order of 100 pCi/g radium will not be detected with a micro-R meter. However, insight can be gained relative to the prevalence of significant NORM occurrence in minerals by such a survey. Table 1 lists the minerals in which radioactivity was detected with the Ludlum survey meter, along with sample size and maximum exposure rate measured.

It may be worthwhile to subject a large collection of minerals to a more sensitive instrument and determine uranium and thorium daughter concentrations. Such a large collection may exist, with the samples ground and weighed already. It should also be noted here that what is reported as insignificant radioactivity by a mineralogist or geologist may be quite significant to a health physicist (only 0.0001 ppm is equivalent to 100 pCi/g radium-226).

TABLE 1

RESULTS OF A RADIATION SURVEY OF SELECTED MINERALS

MATERIAL	ORIGIN	SAMPLE SIZE (lb)	MAXIMUM SURFACE READING (μR/hr)*
Background	—	---	10
Pitchblende	Lakeview, Oregon	1.5	130
Granite	Mariposa Co., California	5	15
Bauxite	Washington Co., Oregon	1	12
Cornwallite	Pershing Co., Nevada	1	12
Plattnerite	Durango, Mexico	1	35
Columbium Alloy	(Man-Made)	0.1	700
Metahewettite	Crook Co., Oregon	5	17
Autunite	Daybreak Mine, Washington	0.2	3000
Copper Ore	Arizona	10	35

*Readings include background.

ATTACHMENT B

Summary of a Meeting on the Radiological Impact of Occupational and Public Exposures in Non-Nuclear Industries and Caves

April 12, 1978

Environmental Protection Agency
Room 1109, Crystal Mall #2
1900 Jefferson Davis Highway
Arlington, Virginia

A meeting was held to discuss the respective jurisdictions, technical information, on-going activities, and future plans of Federal and State agencies in order to evaluate the radiation exposure potential to workers in various non-nuclear industries and workers and the public in caves. Representatives of the National Conference of Radiation Control Program Directors, NIOSH, MESA (now MSHA), OSHA, Bureau of Mines, EPA, National Park Service, and Ozark Underground Laboratory were present. Below is a list of attendees.

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The meeting began with a brief introduction by L. Hall Bohlinger, Meeting Chairman, in which the purpose of the meeting was detailed, an explanation of the formation and function of the National Conference on Radiation Control was given, as was the function of Conference Task Forces, in particularly Task Force No. 7 on Natural Radioactivity Contamination Problems. A copy of the initial task force report was distributed and two areas in the report which more or less served as the basis for this meeting were discussed. These were occupational radiation exposure in non-nuclear industries such as phosphate mining and milling, and occupational and public exposure to radon in public and private caves. It was stated that there were Federal agencies present who had certain responsibilities and jurisdiction in these areas as do the state agencies, and we hope to gain from the meeting, a better understanding as to the breakdown of Federal regulatory authority, and ultimately, we would like to report to the Conference and the States, the ongoing activities, technical information gained, future plans, and any follow-up to this meeting. Hopefully we would gain a clearer understanding of the jurisdictional mechanisms and be in a position to formulate general recommendations.

The next subject discussed was the legislative responsibilities of the respective agencies in the areas of interest. Below is a summary of that discussion:

1. Occupational Safety and Health Administration (OSHA). Authority is limited to occupational exposure in manufacturing and use only in non-nuclear activities, including occupational exposure in caves;

2. Mine Safety and Health Administration (MSHA, formerly MESA). Authority includes occupational exposures to radiation resulting from the mining and milling of materials. MSHA and OSHA have no interface and operate on different standards. MSHA has no State agreement plans after March 9, 1978, since they felt the States did not do an adequate job.

3. Bureau of Mines. Has the responsibility for safety research only in the areas of mining and milling.

4. National Institute of Safety and Health (NIOSH). Is responsible for research in the areas of mining, milling, manufacturing and use. NIOSH supplies input to OSHA, but has no direct authority. NIOSH originated from the Coal Mining Act of 1969, and essentially has no activities in radiation exposure evaluation.

5. The U. S. Forest Service and the U. S. Bureau of Land Management have responsibilities for public safety in caves.

Table 1 is a summary of Federal agencies and their activities in NORM regulation.

OSHA also has authority to regulate occupational exposures from NORM or NARM activities in non-agreement states if the state does not have OSHA agreement in accordance with Section 18(b).

TABLE 1

NORM ACTIVITY	FEDERAL AGENCY	AGENCY FUNCTION
Mining	MSHA	Occupational Exposure
	Bureau of Mines	Safety Research
	NIOSH	Health Research
Milling	MSHA	Occupational Exposure
	NRC (U only)	Regulatory
	NIOSH	Health and Safety Research
	Bureau of Mines	Safety Research
Manufacturing	OSHA	Occupational Exposure
	NIOSH	Safety and Health Research
Use	OSHA	Occupational Exposure (if employee)
	NIOSH	Safety and Health Research
Caves		
Occupational	Forest Service	Occupational Exposure
	Bureau of Land Management	
	OSHA	
Public	Forest Service	Public exposures
	Bureau of Land Management	

Ongoing activities were described as follows:

1. All underground mines are screened once a year by MSHA. Additionally, all mills have been screened at least once. The Task Force should write to MSHA requesting monitoring information. MSHA requires personnel monitoring at levels greater than 2 mR/hr.

2. It was recommended that the National Park Service monitoring program, which was quite comprehensive in nature, be continued.

3. It was recommended that the National Cave Association expand their monitoring program, improve radiation management, and encourage non-members to enforce their suggested guidelines. It was also brought out that there was a need for epidemiological information concerning estimates of risks from occupational exposure. The National Academy of Science is currently re-evaluating the estimates of risk.

4. The EPA is currently reviewing occupational and guidance levels formally of the Federal Radiation Council. This review was to be out for comment by January, 1979. Additionally, the EPA through its Clean Air Act, funded a retrospective study carried out by MSHA, the results of which have not been reviewed.

5. OSHA and NIOSH do not have occupational radiation exposure records.

6. Bureau of Mines was conducting a study of personal dosimetry and instrumentation for non-uranium industry.

Outlined below is a summary of the guidelines which the National Park Service now have under review. They are consistent with those which the cave management industry have also adopted.

PART I - STANDARDS

Interim Precautionary Cave Radiation Health Standards for Natural Caves Open to Visitation by the Public

1. Where a few radiation measurements have been made suggesting a potential radiation health hazard, but where routine radiation monitoring is not done regularly, underground work shall not exceed 700 hours per year for any employee.

2. Where radiation monitoring is done on a routine basis, the annual cumulative radiation exposures will not exceed 4.0 working level months of alpha radiation exposure for any employee.

2A. Where monitoring is done regularly, and adequate data have shown a seasonal repeatability in radiation concentration levels, professional judgement shall be exercised as to the frequency of subsequent monitoring. Employee exposures must be recorded, nevertheless.

2B. For monitored caves where the data base does not show a reasonable predictability in radiation concentration levels for the period being sampled, the following monitoring frequency will be used for monitoring occupied areas during those times when they are being regularly visited by the employees.

WL RANGE	MONITORING FREQUENCY
0 to 0.10	Annual measurement during that season when underground work time is greatest.
0.11 to 0.20	Semi-Annual sampling

WL RANGE	MONITORING FREQUENCY
0.21 to 0.30	Quarterly sampling
Over 0.30	Weekly sampling and record keeping on employee exposure accumulations

NOTE: The WL Range is based upon the average of the values obtained in a single sample set. The maximum average value on record should be used unless collected data suggest that this set is atypical. This table should be used flexibly by cave managers as a "sliding" scale linked with seasonal cave radiation variations.

3. While underground, the smoking of tobacco, either by employees or visitors, is prohibited.

4. Except as provided below, cave air shall not be used to ventilate buildings used by employees or visitors, nor shall cave air be allowed to freely enter such buildings:

Exception 1: Buildings which are used exclusively for entry or exit from a cave are excepted.

Exception 2: Buildings where no individual employee spends an average of more than 5 hours per week are excepted.

Exception 3: Buildings where radiation monitoring indicates that average alpha radiation levels are less than 0.10 working level are excepted. This applies regardless of whether radiation control measures are utilized in the building or not.

Exception 4: Buildings where radiation monitoring indicates that alpha radiation levels are less than 0.30 WL, are excepted if cave air was used for ventilation in the summer of 1977.

5. The potential health hazard of alpha radiation in caves must be explained before they begin their employment to all employees who will be doing any significant underground work. This explanation must be given by someone who is qualified to present a clear and careful discussion of the potential radiation health hazard. Care must be exercised in making this explanation to short-term employees so that a proper understanding of the potential health hazard will be given. This can be accomplished with a well written pamphlet, supplemented by a verbal explanation.

PART II - MANAGEMENT GUIDANCE

Interim Management Guidance for the Protection of Health from Alpha Radiation in Natural Caves Open to Visitation by the Public.

1. Development of excursion limits or maximum alpha radiation concentration levels in natural caves does not appear to be necessary at this time. However, it is recommended that management minimize the cumulative exposure of both employees and visitors as much as possible. Such actions should not adversely affect the cave or adversely affect the quality of the experience of the cave visitor.

2. The concentration of alpha radiation in caves should not be used as justification for either temporary or permanent closure of caves.

This applies both to developed and wild caves. However, positive management actions designed to reduce human exposure to higher alpha radiation levels are appropriate so long as such actions do not adversely affect the caves or adversely affect the quality of the experience of the cave visitor.

3. The artifical ventilation of caves and/or the use of cave air for ventilating surface building has major adverse impacts and should be avoided. Such actions can have detrimental impacts on cave fauna and cave features, and can damage the natural integrity of the cave.

4. Particularly at caves where alpha radiation concentrations commonly exceed 0.30 WL and where employees spend substantial amounts of time working underground, periodic medical examinations seem appropriate. At such caves, a pre-employment examination (which includes a sputum sample for pulmonary cytology) seems advisable. After an employee has worked in a cave regularly for over 5 years, annual sputum samples for pulmonary cytology seem again advisable.

5. Evaluation of the data indicates that the potential health hazard of cave radiation does not warrant classification of underground work in caves as hazardous duty.

6. Cavers visiting wild caves should be informed of the spectrum of hazards and potential hazards which they may encounter. Cave radiation is one of these potential hazards, but may not be the most significant hazard in any given cave. In wild caves known to have

high radiation concentrations during certain seasons of the year, cavers should be informed of the best time of year to visit such caves. Cave radiation concentrations should not be used as justification for limiting access or closing caves.

7. Survey data suggest that a majority of cave employees do not go caving in off-duty hours. Those who do go caving usually experience modest exposures from this activity. Generally, it does not seem necessary to record off-duty exposure time, or to add such time to the cumulative exposure for the employee. Such addition of off-duty exposure to an employee's cumulative total may be at the discretion of the manager.

8. The proposed "Interim Precautionary Cave Radiation Health Standards for Natural Caves open for Visitation by the General Public" require that the potential health hazard to alpha radiation in caves be explained to all employees who will be doing any underground work before they begin their employment.

PART III - SCIENTIFIC INFORMATION

Interim Guidance for Data Collection for Natural Caves Open to Visitation by the Public.

In order to make the most effective resource management decisions for caves which will be both prudent and proper in the long-term phase of the radiation program, it is important to continue to develop the data base. This is to be done by continued routine monitoring, where applicable, using the above standards (Part I) and Management Guidelines (Part III), at caves now being monitored - especially those administered by the NPS.

In addition, managers should recognize the importance of a continuing cooperation with scientific professionals. This will insure that appropriate skills will be mustered which can assist in developing the quantitative basis for establishing sound management plans and actions, by implementing pertinent applied research efforts. Conversely, managers, can provide questions, ideas and facts useful in shaping such research so that it can produce management oriented results.

ATTACHMENT C

Examples of Risk-Benefit Analyses Applied to the Uses of Products or By-Products Containing NORM

It must be emphasized that the examples given below do not represent real risk-benefit analyses and that the numbers used were assumed for purposes of the example. Some of the considerations to be used in performing the analysis are:

(1) Changes in risks, benefits, and costs over time.

(2) Inclusion of all costs and risks both short and long term.

(3) Treatment on a case-by-case basis using different cost criteria as necessary.

(4) Use of weighting factors for organ doses as specified in ICRP 26.

EXAMPLE 1
Tape Dispensers

Problem: The external radiation rate from a tape dispenser containing zircon sand is about 1/3 μR/hr at a distance of two feet. The question is, should the distribution of dispensers emitting these small but above background radiation levels be prohibited?

Assumptions: Assume that there are a total of 500,000 tape dispensers in use and that it is estimated that 1/2 of these will contain or continue to contain zircon sand if use of the dispensers is not prohibited. Assume that secretaries are exposed to these tape dispensers for six hours per day at two feet for 250 days per year. Assume that use of the zircon sands in tape dispensers presented no economic advantage over the use of some other non-radioactive dense material.

Person-rem: The person-rem from use of tape dispensers is estimated as:

250,000 dispensers x 1/3 μrem/hr x 1 person/dispenser x

6 hr/day x 250 days/yr = 130 person-rem/yr

Radiation Cost: The radiation cost as the result of the use of radioactive tape dispensers is:

130 person-rem/yr x $1,000/person-rem = $130,000/yr

Costs of Eliminating Radiation. The costs of eliminating this dose pathway is zero. This is because it was assumed that there was no economic advantage in using zircon sand over some other dense material.

Conclusion: Zircon sands should not be used in tape dispensers. This would be true regardless of the radiation levels from the dispensers because there are no benefits unique to the use of zircon sands for this purpose.

EXAMPLE 2
Fertilizers

Problem: Superphosphate fertilizer contains about 20 pCi/g of radium-226. The fertilizer is made by bringing phosphoric acid into contact with the basic phosphate ore in order to increase the phosphorus content. Radium is contained in the ore and becomes a contaminate in this particular fertilizer. The question is, should the manufacture of superphosphate be prohibited? Should fertilizer manufacturers be required to introduce non-radioactive phosphorus into phosphoric acid in order to manufacture superphosphate?

Assumptions: Assume that the use of radioactive superphosphate results in an average internal radiation exposure of 0.01 mrem/hr to each individual in the United States due to the application of the fertilizer to agricultural lands. (Occupational exposures from the handling of the fertilizer shall be ignored.) Assume that the costs of not using superphosphate due to reduced food crop production is $100,000,000 per year. Assume that the cost of manufacturing superphosphate by the introduction of elevated phosphorus if $1,000,000 per year more than the cost of manufacturing superphosphate by using basic phosphate ore.

Person-rem: The total population dose commitment from superphosphate use is:

$$200 \times 10^6 \text{ persons} \times .01 \text{ mrem/yr} = 2{,}000 \text{ person-rem/yr}$$

Radiation Cost: The radiation cost of using superphosphate is:

$$2{,}000 \text{ person-rem/yr} \times \$1{,}000/\text{person-rem} = \$2{,}000{,}000/\text{yr}$$

Cost of Eliminating Radiation: If the manufacture of superphosphate is prohibited, $10,000,000 is lost in food production. If phosphate plants are required to manufacture superphosphate by an alternative method, the cost is $1,000,000 per year.

Conclusion: Phosphate plants should use an alternative method to manufacture superphosphate in order to prevent radioactive contamination of the fertilizer. Or, radioactivity in superphosphate should be reduced by 1/2.

EXAMPLE 3
Phosphate Slag for Road Construction

Problem: There is a shortage of gravel and other aggregate in a particular area of the country. As a consequence, readily available phosphate slag from a local phosphate plant is crushed and used as an aggregate in road construction. The slag contains radioactivity and the average exposure rate three feet above a street or highway utilizing slag is 30 μR/hr (net). In the next 20 years, an average of 100 miles of road will be constructed or rebuilt using slag each year. It takes 100,000 tons of aggregate to build 100 miles of road. Slag costs $10 per ton (including transportation costs). The question is, should the use of slag for road construction be prohibited?

Assumption: Assume that the exposed population group is 30,000 person/yr. Assume that the occupancy factor on roads is 1/16. (Radon exposures and off-road exposures shall be ignored in this example).

Person-rem: The population dose commitment for the 20-year activity period is:

$$30\ \mu R/hr \times 1/16 \times 24\ hr/day \times 365\ days/yr \times 20\ yr \times 10^{-6}\ rem/\mu R \times 30{,}000\ persons = 10{,}000\ person\text{-}rem$$

Radiation Costs: 10,000 person-rem x $1,000/person-rem = $10,000,000

Costs of Eliminating Radiation: $40/ton - $10/ton = $30/ton additional cost for nonradioactive agregate

$30/ton x 100,000 tons/100 miles = $3,000,000/100 miles of road

In 20 years:

$3,000,000 x 20 = $60,000,000 additional cost for nonradioactive aggregate

Conclusion: Slag could be used as aggregate in road construction for at least the next 20 years at the rate given. However, it is assumed that the radiation exposure ceases after 20 years. This obviously may not be the case. An appropriate length of time to carry out the exposures appears to be at least one generation. A conservative assumption would be 100 years of exposure. By then, road surfaces built in the first 20 years would probably be widely dispersed and even removed from man's environment to a degree. Using 100 years of exposure results in increasing the population dose commitment by a factor of 5.

This raises the radiation cost to $50,000,000 which is still below the $60,000,000 additional cost of using nonradioactive aggregate.

In view of these considerations and under the assumptions given, there appears to be reasonable justification for using phosphate slag as an aggregate in road construction.

EXAMPLE 4
Construction on Monazite Sands

Problem: A developer proposes to build a housing project in an area containing naturally occurring and undisturbed monazite sands. The monazite sands are radioactive. Will the developer be in violation of the NORM regulations proposed in this report?

Answer: The developer is not in violation of any of the proposed requirements because products or by-products are not involved. A responsible regulatory agency would point out the increased radiation background, however, and perhaps take steps to inform prospective buyers of the degree of risk.

ATTACHMENT D

NATURALLY OCCURRING RADIONUCLIDES

The naturally occurring radionuclides in the earth's biosphere can be divided into two basic groups:[1, 2, 3]

(a) radionuclides that are being continually produced by nuclear reactions of cosmic rays with the earth's atmosphere or in the earth's upper crust;

(b) radionuclides that are present in the earth's atmosphere or upper crust either because they have half-lives comparable to the age of the earth or because they are being continually produced by decay of long-lived parent radionuclides.

A list of radionuclides with half-lives longer than thirty minutes that are produced by cosmic ray interaction with the earth's atmosphere is shown in Table 1. Those radionuclides that contribute a measurable dose to man are hydrogen-3, carbon-14, sodium-22 and beryllium-7.

The long-lived (or primordial) radionuclides can generally be divided into non-series (singly-occurring) and series radionuclides. Non-series, long-lived radionuclides are shown in Table 2. Some of the radionuclides do not emit detectable radiations. Only potassium-40 and rubidium-87 are significant sources of radiation with concentrations of about 17 pCi and 2 pCi per gram of crustal rock, respectively.[3]

There are four naturally occurring radioactive series of radionuclides headed by uranium-238, uranium-235, thorium-232, and plutonium-241. The neptunium series headed by plutonium-241 is found in nature only in minute quantities because of its lack of a long-lived precursor. The actinium (uranium-235) series is less important than the uranium-238 and thorium-232 series since uranium-235 comprises only 0.72%

by weight of natural uranium. The activity ratio of uranium-235/uranium-238 is less than 0.05.[2, 3] The four series are listed in Tables 3, 4, 5, and 6.

Discussions of the dose due to the naturally occurring radionuclides are given in references 3 and 5.

Radionuclide half-lives for Tables 1, 3, 4, 5 and 6 are taken from Reference 6. The half-lives of the radionuclides listed in Table 2 are so long that in some cases, there may be a question as to whether the nuclide is really radioactive. Where available, half-lives are taken from Reference 6.

TABLE 1. Radionuclides Produced in the Atmosphere by Cosmic Rays

Radionuclide	Half-life
Hydrogen-3	12.33 years
Beryllium-7	53.3 days
Beryllium-10	1.6×10^6 years
Carbon-14	5.73×10^3 years
Fluorine-18	109.8 minutes
Sodium-22	2.602 years
Sodium-24	15.02 hours
Aluminum-26	7.2×10^5 years
Magnesium-28	21.0 hours
Silicon-31	2.62 hours
Silicon-32	650 years
Phosphorus-32	14.28 days
Phosphorus-33	25.3 days
Chlorine-34m	32.10 minutes
Sulfur-35	87.4 days
Chlorine-36	3.00×10^5 years
Argon-37	35.0 days
Chlorine-38	37.3 minutes
Sulfur-38	170 minutes
Chlorine-39	56 minutes
Argon-39	269 years
Krypton-81	2.1×10^5 years
Krypton-85	10.7 years

TABLE 2. Non-Series Radionuclides with Half-Lives Greater Than 10^7 Years

Radionuclide	Half-life (Years)	Reference
Potassium-40	1.28×10^9	6
Calcium-48	$>7 \times 10^{18}$	4
Vanadium-50	6×10^{15}	3
Selenium-82	1.4×10^{20}	6
Rubidium-87	4.8×10^{10}	6
Zirconium-96	6×10^{16}	4
Cadmium-113	9×10^{15}	6
Indium-115	5.1×10^{14}	6
Antimony-123	$>1.3 \times 10^{16}$	4
Tellurium-123	1.2×10^{13}	3
Tellurium-128	1.5×10^{24}	6
Tellurium-130	2×10^{21}	6
Iodine-129	1.6×10^{7}	6
Lanthanum-138	1.1×10^{11}	6
Cerium-142	$>5 \times 10^{16}$	3
Neodymium-144	2.1×10^{15}	6
Neodymium-145	$> 10^{17}$	7
Neodymium-150	1.5×10^{15}	1
Samarium-146	1.03×10^{8}	6
Samarium-147	1.06×10^{11}	6
Gadolinium-152	1.1×10^{14}	6
Dysprosium-156	$>1 \times 10^{18}$	4
Lutecium-176	3.6×10^{10}	6
Hafnium-174	2.0×10^{15}	6
Tantalum-180	$>1.0 \times 10^{13}$	6
Tungsten-180	$>2 \times 10^{17}$	4
Rhenium-187	4×10^{10}	6
Osmium-186	2×10^{15}	6
Platinum-190	6×10^{11}	6
Platinum-192	1×10^{15}	3
Lead-204	1.4×10^{17}	7
Bismuth-209	$>2 \times 10^{18}$	3
Plutonium-244	8.1×10^{7}	6

TABLE 3. Uranium Series

Radionuclide	Half-Life
Uranium-238 (Uranium I)	4.468×10^9 years
Thorium-234 (Uranium X_1)	24.10 days
Protoactinium-234m (Uranium X_2)	1.175 minutes
Protoactinium-234 (Uranium Z)	6.75 hours
Uranium-234 (Uranium II)	2.45×10^5 years
Thorium-230 (Ionium)	8.0×10^4 years
Radium-226	1600 years
Radon-222 (Emanation)	3.8235 days
Polonium-218 (Radium A)	3.05 minutes
Lead-214 (Radium B)	26.8 minutes
Astatine-218	2 seconds
Bismuth-214 (Radium C)	19.7 minutes
Polonium-214 (Radium C')	1.64×10^{-4} seconds
Thallium-210 (Radium C'')	1.3 minutes
Lead-210 (Radium D)	22.3 years
Bismuth-210 (Radium E)	5.01 days
Polonium-210 (Radium F)	138.38 days
Thallium-206 (Radium E'')	4.20 minutes
Lead-206 (Radium G)	Stable

TABLE 4. Thorium Series

Radionuclide	Half-Life
Thorium-232	1.41×10^{10} years
Radium-228 (Mesothorium I)	5.76 years
Actinium-228 (Mesothorium II)	6.13 hours
Thorium-228 (Radiothorium)	1.9131 years
Radium-224 (Thorium X)	3.66 days
Radon-220 (Emanation, Thoron)	55.6 seconds
Polonium-216 (Thorium A)	0.15 seconds
Lead-212 (Thorium B)	10.64 hours
Bismuth-212 (Thorium C)	60.6 minutes
Polonium-212 (Thorium C')	3×10^{-7} seconds
Thallium-208 (Thorium C'')	3.053 minutes
Lead-208 (Thorium D)	Stable

TABLE 5. Actinium Series

Radionuclide	Half-Life
Uranium-235 (Actino uranium)	7.038×10^{8} years
Thorium-231 (Uranium Y)	25.52 hours
Protoactinium-231	3.28×10^{4} years
Actinium-227	21.773 years
Thorium-227 (Radioactinium)	18.718 days
Francium-223 (Actinium K)	21.8 minutes
Radium-223 (Actinium X)	11.435 days
Radon-219 (Emanation, Actinon)	3.96 seconds
Polonium-215 (Actinium A)	1.78×10^{-3} seconds
Lead-211 (Actinium B)	36.1 minutes
Astatine-215	10^{-4} seconds
Bismuth-211 (Actinium C)	2.15 minutes
Polonium-211 (Actinium C')	0.516 seconds
Thallium-207 (Actinium C'')	4.77 minutes
Lead-207 (Actinium D)	Stable

TABLE 6. Neptunium Series

Radionuclide	Half-Life
Plutonium-241	14.4 years
Americium-241	433 years
Uranium-237	6.75 days
Neptunium-237	2.14×10^{6} years
Protoactinium-233	27.0 days
Uranium-233	1.592×10^{5} days
Thorium-229	7.3×10^{3} years
Radium-225	14.8 days
Actinium-225	10.0 days
Francium-221	4.8 minutes
Astatine-217	3.23×10^{-2} seconds
Bismuth-213	45.6 minutes
Polonium-213	4×10^{-6} seconds
Thallium-209	2.2 minutes
Lead-209	3.25 hours
Bismuth-209	Stable

References

1. Pertsov, L. A. The Natural Radioactivity of the Biosphere. AEC-tr-6714. Atomizdat. 1964. Moscow, U.S.S.R.

2. Lowder, W. M. and L. R. Solon. Background Radiation - A Literature Search. NYO-4712. July 1956. U. S. Atomic Energy Commission Health and Safety Laboratory, New York, NY.

3. Natural Background Radiation in the United States. NCRP Report No. 45. November 15, 1975. National Council on Radiation Protection and Measurements, Washington, D.C.

4. Radiological Health Handbook. January 1970. U. S. Department of Health, Education, and Welfare. Rockville, Maryland.

5. Radiological Quality of the Environment in the United States, 1977. EPA-520/1-77-009. September 1977. U. S. Environmental Protection Agency, Office of Radiation Programs. Washington, D.C.

6. Lederer, C. M., Hollander, J. M., and Perlman, I. (1978). Table of Isotopes, 7th ed. (John Wiley & Sons, New York).

7. Walker, F. W., Kirovac, G. J., and Rourke, F. M. (1977) General Electric Chart of the Nuclides, Twelfth Edition. (General Electric Company, Schenectady, New York.

RECOMMENDATIONS

A. Pending the establishment of appropriate standards, the use of phosphate mining and milling byproducts in occupied structures should be discouraged if they contain elevated levels of radium-226. EPA should place high priority on evaluating this application of these byproducts and balancing this against the environmental problems associated with waste storage of the materials.

B. Phosphate byproducts, particularly gypsum, are presently used to a limited extent as agricultural soil conditioners. Although little is specifically known regarding the environmental impact of this use, and considering the small addition of radioactivity to the environment, it is unlikely that this application would result in significant radioactivity uptake in crops. It is not recommended that this use of the byproduct materials be discouraged at this time. Additional controlled studies should be performed to document the anticipated minimal environmental impact of this use.

C. Slag from thermal process phosphorus acid plants should not be used for any purpose that results in its being under or within an enclosed structure. Any other use of slag should be thoroughly evaluated.

D. States, where applicable, should adopt regulations pertaining to control of radioactive miners' tailments and industrial byproduct piles. States should investigate their statutory authority over naturally-occurring radioactive material and if necessary, enact appropriate legislation.

E. The States should perform additional radiological air monitoring inside and outside phosphate plant areas.

F. States should inventory mineral mining and processing operations referred to in Part VI of this report, and examine potential radiological aspects of their

effluent, emissions, products and wastes. A report of the inventory and other findings should be submitted to Task Force #7 with any pertinent recommendations.

G. This Task Force as a representative of the Conference, should meet with EPA, NIOSH, OSHA and MESA and discuss their respective jurisdictions and activities regarding occupational radiation exposure in the phosphate industry.

H. EPA should study the uptake of naturally-occurring radionuclides in food crops from irrigation water, fertilizer, and radiation-bearing soil.

I. EPA should study the whole body and organ doses resulting from ingestion of radon daughters in drinking water.

J. EPA should evaluate the inhalation hazard which may result from the release of radon from water containing high concentrations of naturally-occurring radioactive material during certain home and commercial uses.

K. EPA should develop national criteria and guidelines concerning the use and distribution of industrial byproducts containing naturally-occurring radioactive material. The EPA should consider seeking appropriate authority to promulgate such guidelines as national standards.

L. EPA and appropriate States should study and evaluate all uses of fly-ash from coal-fired plants, particularly related to construction materials.

M. The radiological aspects of each proposed coal-fired plant should be evaluated by the appropriate agencies. Radioactive releases should be estimated from an analysis of the coal to be consumed and the operating characteristics of the proposed plant. This recommendation is especially pertinent to any proposed plant that intends to derive its fuel from low-grade, uraniferous Western coals.

N. The EPA should develop standard procedures and guidelines for sample collection and analysis of naturally-occurring radioactive material to ensure the

acquisition of uniform and comparable data by State and Federal programs. The EPA should expand their cross-check quality assurance program in conjunction with the standard analytical procedures and to include NORM.

O. The States, the EPA, or other appropriate agencies should proceed to measure radon levels on fly ash piles and in structures built in fly ash disposal areas, if such case exists.

P. It is recommended that representatives of this Task Force, EPA, NIOSH, and MESA meet to discuss the preliminary investigations and measurements of radon-222 in caves and determine what other studies should be undertaken to properly evaluate this situation. Additionally, the interim recommendations made on the basis of existing Federal guidance for the protection of underground uranium miners should be evaluated as additional information and data are obtained.

Q. This Task Force recommends that a thorough evaluation be undertaken concerning the occurrence of radon-222 as a source of possible radiation exposure in State and privately-owned caves.

R. In view of the measured high concentration of radium-226 in oil brines, the impact of uncontrolled discharge of these brines on the biosphere should be evaluated by appropriate State and Federal agencies. The proposed study in Attachment E to investigate this impact should be considered for funding by EPA or other appropriate agencies.

S. Phosphate industries and all other industries having significant radiological impacts should be licensed in order to assure adequate controls over naturally-occurring radioactive materials.